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John W. Waldron

(Extract from Minutes of a Meeting of the Trustees, H.S.P.A., August 23, 1935.)

It is with profound regret that the Trustees of the Hawaiian Sugar Planters' Association record the death of Mr. John W. Waldron, which occurred in Honolulu on Saturday, August 17, 1935.

Mr. Waldron first became associated with the sugar industry in Hawaii in 1899. He was elected a member of this Association in 1907 and a Trustee in 1911, serving as president in 1921-1922 and 1931-1932. He was appointed a member of the Experiment Station Committee in 1908 and served almost continuously on that committee for twenty-five years and as its chairman for eight years. He had a thorough understanding of every phase of the work being carried on at the Experiment Station and was particularly interested in the control of cane insects and diseases and the development of new cane varieties. It was largely through his influence that the ban on the importation of foreign canes was lifted in 1923. The new canes brought in since that time have already placed the local sugar crop on a much broader and firmer foundation.

He strongly advocated the reforestation of our watersheds and took an active part in the development of a forestry department in the Station.

It has been his privilege to visit almost every sugar producing country in the world, making a study of conditions prevailing in each section involving economic effects applying to the production of cane sugar in Hawaii. He kept very complete statistics pertaining to all branches of the industry, which data were always available to those actively associated with the industry, here in the Islands. This information afforded him the opportunity of rendering valuable services as a representative of the industry at Washington at tariff hearings, and on different occasions in connection with national legislative and administrative matters.

He served as a delegate to several important international sugar conferences and was regarded as being unusually well informed on all matters pertaining to the sugar industry throughout the world.

He was respected and highly esteemed by all of his associates for his friendliness, unfailing courtesy and hospitality, unusual ability and genial personality.

As a token of our esteem for him as a business associate, wise counsellor and friend, we, the Trustees of the Hawaiian Sugar Planters' Association, take this means of recording our high regard for John W. Waldron and our recognition of his outstanding ability and character, and offer this tribute to be inscribed on the minutes of this meeting.

We extend to his family and members of the firm of which he was the president and manager our sincere sympathy in their bereavement.

In This Issue:

Utilization of Molasses:

Under this heading notes are given on the progress of the work on utilization of the principal by-product of the sugar industry. One of the most attractive possibilities, which is discussed briefly in this issue, is the manufacture of anhydrous alcohol for use in blended motor fuel.

Sugar in Australia:

It is often of interest to learn how the "other fellow" lives and grows his sugar cane. Our delegates to the 1935 International Congress of Sugar Cane Technologists had an opportunity to see how sugar is grown and handled in Australia, and an account of their impressions brings out many points of difference between this Australian industry and ours.

Growth-Failure Problems:

In so far as the so-called "growth-failure" spots represent aggravated effects of deleterious factors which are depressing cane growth in a less pronounced degree over wide areas, they are of special interest to the investigator. The present status of the growth-failure investigations is reviewed and attention is called to some problems which remain to be solved.

Irrigation Labor Requirements and Fixed Charges:

Considerable interest has been shown by the industry in general in the reduction of labor requirements for irrigation. In this article the various factors entering into the initial cost of the particular installation contemplated are discussed together with other factors such as the life of the installation, fixed monthly charges, etc., all of which have a bearing on whether or not the installation will be economical. A chart is presented by means of which the fixed charges of the various phases of irrigation may be estimated. This chart may also be utilized to obtain necessary information about other operations on the plantation.

Life-History Studies of Anomala Orientalis:

Investigations on the life history and general habits of the sugar cane root grub *Anomala orientalis* were made by F. A. Bianchi at Oahu Sugar Company, Ltd., without interruption for an extended period. The results of this research are given in detail.

Emergency Conservation Work in Hawaii:

With the kind consent of E. E. Tillett, Field Supervisor, Emergency Conservation Work for Hawaii, we print a report by Albert Duvel which sets forth all the details of the CCC organization on the Island of Kauai.

Resumé of Papers Presented at the Brisbane Congress:

Short abstracts of papers delivered before the agricultural section at the Fifth International Congress of Sugar Cane Technologists that was held in Australia are offered. All papers, in full, will appear in the "Proceedings" of this Congress and should be available in Hawaii early in 1936.

A Guatemalan Sugar Cane Moth Borer:

Here are given the results of observations in Guatemala on a large moth borer that tunnels the stems of different kinds of plants including the sugar cane. The insect was found in a limited area and was not very numerous in sugar cane, but the cane stem attacked by it often broke at the point of severest injury. Sugar cane is probably not the preferred host of this moth borer.

The male moths fly for a very short time at dusk. The female lays a large number of eggs which she probably scatters over the ground.

This pest is controlled to some extent by ants and a parasitic fly.

The Fluctuations of Sugars in the Leaf Blades of the Sugar Cane Plant During the Day and the Night:

The blade of a sugar cane leaf varies in its chemical composition during the day and the night. The moisture content is least in the early afternoon and greatest in the early morning. The cane sugar content is at its maximum at five or six o'clock in the evening and decreases rapidly during the night. In this investigation sucrose did not at any time disappear entirely from the blades. The relationships between these and several other constituents of the leaves are discussed, with particular emphasis upon the problem of the origin of sucrose in the sugar cane plant.

Liming Acid Soils:

Heavy lime applications on acid soils generally have an adverse effect on juice quality. The experiment reported here attempts to study in somewhat more detail the effect of lime on purity, quality ratio, and glucose. The findings are summarized and presented graphically.

Ceresan Treatment of Seed Cane:

Ceresan is generally acknowledged to be an aid in securing good germination of seed cane during wet and cold weather.

The present test was undertaken chiefly to determine if there was shoot stimulation in addition to increased germination. The results indicate that while H 109 seed germinated better, the shoots were not stimulated but rather depressed by the Ceresan treatment.

Utilization of Molasses

Studies now in progress on products which can be made from waste molasses indicate that several possibilities are worthy of further exploration. One which fits remarkably well into present conditions is the manufacture of anhydrous alcohol to be used in blended motor fuel.

Gasoline containing from 5 per cent to 25 per cent anhydrous alcohol burns in motors of present design with efficiency equal to that of pure gasoline and with no change in carburetor adjustment. It is particularly well adapted to use in the high compression motors of recent years, on account of its high anti-knock value, making the use of tetra-ethyl lead or other anti-knock compounds unnecessary.

Countries without an adequate domestic supply of petroleum have long been carrying on experimental work on alcohol-gasoline blends, and the commercial use of such blends is well under way. In many of these countries an additional motive has been to aid in the disposal of various sorts of surplus material from the agricultural industries. In Sweden, where there is no compulsory legislation, the use of anhydrous alcohol in motor fuel increased from 8,000 gallons in 1922 to 2,150,000 gallons in 1931. In France and Germany, where a small differential tax favors the use of alcohol blends, the latest figures available (1932) show the annual use of 20 million and 46 million gallons of alcohol respectively.

Although the petroleum companies in Europe have generally opposed such blends at first, their attitude is changing and the fuel is now usually blended and distributed by the petroleum industry. In England the Cities Service Company, and in Australia the Shell Company market alcohol blends which are said to be superior to ordinary gasoline.

In Hawaii the annual consumption of gasoline is in the neighborhood of 40 million gallons. To replace 10 per cent of this with anhydrous alcohol would require the use of 60,000 tons of molasses as raw material. The potash from this molasses would be found in the fermentation residue, in an improved condition for use as fertilizer. Other by-products of the process, such as glycerol, fusel oils, and carbon dioxide, are marketable.

From the Fifth Report of the Federal Oil Conservation Board, October 1932:

> An analysis of the oil reserves of the United States, based upon the consensus of well-founded opinions, indicates that present known recoverable oil reserves in the U. S. are of the magnitude of ten billion barrels . . . . the equivalent of our present known oil reserves will have been withdrawn from their underground reservoirs in ten to twelve years.

Certain strains of *Aspergillus niger,* a well-known mold, have been found to be efficient producers of citric acid from the sugars in molasses. Work on this process is being carried on.

Several microorganisms have been isolated here from molasses in storage and from spontaneous fermentation of dilute molasses in one of the sugar mills. Results of fermentation with these organisms bear out previous experience that native strains are often most efficient because they are generally best adapted to the raw material used.

A. R. Lamb.

Sugar in Australia

By R. J. Borden

To the "man in the street" in Sydney, New South Wales, there is no excuse for government maintenance of a cane sugar industry in Queensland; to his counterpart in Brisbane, Queensland, this subsidized cane sugar industry is absolutely necessary for his welfare and livelihood. To the political leaders of the Labor Party in Australia, the sugar industry offers a solid block of many thousands of votes; to the opposition it is a target at which they continually hurl charges of "an artificial and uneconomic industry" which the average family has to pay for when it buys sugar. To the nationalist, government support for this industry means his preference for a well-populated, resident-farmer district to the north of Australia's principal cities, rather than the necessity of maintaining fortifications and a plan of coast defense for this long unprotected coast line. Thus any discussion of their sugar industry is apt to be very controversial.

A few general comments on the Australian sugar industry are in order before proceeding to a discussion of their field and milling practices.

Organization

The industry is almost completely under government control, with the Queensland state government responsible for maintaining adequate supplies of sugar for the whole of Australia, the Commonwealth government prohibiting imports, and both of these governments agreeing on the price at which refined sugars will be sold within the Commonwealth. Wages and hours in all branches of the industry are fixed by laws of the Queensland Industrial Court; these are very specific. Prices to be paid by the mill owner to the grower for his cane are fixed by the government's Central Cane Price Board, which is presided over by a Supreme Court judge. This Cane Price Board also makes the land assignments upon which cane may be grown, and only cane grown on these assigned lands is entitled to the benefits of awards under the Sugar Cane Price Acts. These land assignments are non-transferable and the right to grow cane thereon goes with the deed to the land when it is sold. Local Cane Price Boards, one for each mill, have representatives of both growers and millers and are presided over by a government official as local chairman. They maintain a government chemist at each mill during the grinding season.

All raw sugar becomes the property of the Queensland government as soon as it is bagged, and the mill owner is paid for it at prices fixed by government order. The same price for raw sugar is paid to all mills throughout the state, i.e., the mill which is a long distance from the refinery actually receives the same price for its raw sugar as the mill adjacent to the refinery. The present scale of prices gives the grower about 71 per cent of the value received by the miller for his raw sugar.

The government employs the Colonial Sugar Refining Company to handle practically 96 per cent of its raw sugar. Their agreement covers transportation to the

refinery, payment of the fixed raw sugar prices to the millers, refining, selling the refined sugar at fixed wholesale prices within Australia, and marketing the surplus sugar (about 44 per cent of that produced) outside of Australia.

In addition to the Cane Price Board, a government edict requires every cane grower to belong to the Cane Growers' Council. This council has local representation from both the growers and the Australia Workers' Union, and concerns itself with the adjustment of difficulties between these two factions.

A Bureau of Sugar Experiment Stations at Brisbane directs and operates three substations, at Bundaberg, Mackay and Meringa, each with a well-trained technical staff. This Bureau is organized under the Minister of Agriculture and guided by an Advisory Committee made up of government appointees and representative growers and mill owners.

There are 33 mills in Queensland and 3 in New South Wales. These 36 mills put out about 660,000* tons of sugar annually, from some 240,000 acres which are harvested yearly from the total of 300,000 acres that are under cane cultivation. (The average sugar production for the last 10 years has been 2.66 tons per acre.) Since Australia consumes only 375,000 tons** of its sugar, it must sell the rest as export sugar. This export sugar does not receive the internal price but it does enjoy a preferential price of 0.9 cent over the open-world price, in Great Britain and Canada.

Each mill is being operated under what is known as a "Peak Year Quota." This quota is based on the highest production made by the mill prior to 1929. All sugar that is made up to the limit of this quota is paid for in the exact proportion of the annual quantity consumed in Australia and the amount sold overseas. Any sugar made in excess of this quota is paid for at its export value only. Since the internal price paid for raw sugar is set at $82.00† per ton and as the excess production in 1934 brought only $27.00 per ton, there is no object in producing export sugar. (The average price received by the farmer for the last three years has been $58.00; this year he expects to receive $55.50, of which $50.00 is being paid outright and the balance held until the final rates are adjusted.)

Because of this "Peak Year Quota" each mill tells the grower how much cane he may deliver to the track line weekly during the grinding season. This cane must come from specific land areas that have been officially assigned to cane growing; no new land and no land exchange may be used.

Fifty per cent of the cane grown comes to 18 cooperative mills; 25 per cent comes to mills owned by the Colonial Sugar Refining Company, and the other 25 per cent goes to other privately owned mills.

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* All tonnage figures are "short" tons that have been converted from "long" tons.

** This is a high per capita sugar consumption and may be compared with other places as follows: (1) Denmark at 135 pounds; (2) Australia at 124 pounds; (3) Hawaii at 117 pounds; (4) United Kingdom at 116 pounds; (5) Switzerland at 114 pounds; (6) Sweden at 110 pounds; (7) U. S. at 108 pounds; (8) Canada at 102 pounds; and Italy at 18 pounds; Central America at 16 pounds; Soviet Union at 13 pounds and China at 3 pounds per capita.

† All currency figures have been converted from Australian pounds, shillings, and pence on the basis of $4.00 per Australian pound.

In 1904, a group of mills which was heavily indebted to the government was taken over and operated by the government. This operation was not successful, so in 1911 the Cooperative Act was passed and the mills were turned back to the growers. (They still owe the government some three and a half million dollars.) The present cooperative mills are of two kinds; (1) those owned entirely by the growers, and (2) those controlled by outside capital. Each has its own charter, and each stockholder is entitled to one vote only, regardless of the amount of stock he holds. They elect directors for a three-year term, and these directors appoint the mill manager. A certain amount of the profit made by the mill must go into a reserve fund to be used in "lean" years. However, the directors tend to pay out the profits and to let the milling plant and equipment run down. These cooperative organizations enjoy cooperative buying privileges, and the farmers receive more money for their cane, so that at the end of the year there will be a few profit-taxes to pay the government.

All cane field and factory workers, except members of the farmer's family, are required to hold membership in the Australian Workers' Union, and non-union labor may not be employed as long as union labor is available. The Industrial Court of Queensland has laid down a definite set of regulations covering the signing on of laborers, their working hours, accommodations, food, holidays, lost time, and time and amount of payment for the various kinds of work done. They have set down specific terms of agreements with cane cutters. Thus, the 28,000 laborers in the sugar industry are adequately protected and paid for their work, and the 8,000 cane farmers can like it or not, just as they please. Naturally the farmers do not like this labor situation, especially since (according to a public address by the Minister of Agriculture at the dedication of the new Meringa Experiment Station) "the average income of the average cane farmer is little if any better than the average income of the average worker who has no capital invested in the industry." Thus it would appear that the protection being afforded by the Australian government to its sugar industry is quite definitely for the benefit of labor and is probably not aimed at that happy prosperous small-farmer population which the nationalist wants to see established along the Queensland coast.

Agricultural Practices

Any discussion of the agricultural practices in the Australian sugar industry must be informative and will unconsciously be comparative. A comparative review of an industry that is conducted under a set of very different economic and political, as well as agronomical conditions, particularly when such a review is made by one who has had only a very brief contact with it, is difficult to present and may even be unfair. However, I shall try to give you some of the general impressions that the sugar industry in Australia has left with me. Many of the data were secured from individual opinions, and we had little opportunity to review reliable data; hence, some of our observations may not be reliable. They are offered, however, in good faith with the hope that they are approximately correct and without too great discrepancies.

Environmental Factors: The excellent natural conditions of climate, soil, and

water, that favor the sugar-growing regions of Queensland are in a large way responsible for the fact that they grow there "the sweetest cane in the world." An idea of these favorable climatic conditions may be gathered from Table A which shows the average temperatures and humidity and total rainfall during the growing and harvesting seasons for the principal sugar-growing centers. Higher maximum temperatures, higher minimum temperatures, higher humidities, and greater rainfall occur during the growing season, when such factors make for rapid cane growth, and the cooler temperatures, lower humidities, and dry weather come when it is most desired to favor good juices.

TABLE A—QUEENSLAND CLIMATIC DATA

District	Growing Season—December to May (inclusive)				Harvest Season—June to November (inclusive)				Total Annual Rainfall
	Mean Max. Temp.	Mean Min. Temp.	Relative Humidity	Inches Rainfall (6 Mos.)	Mean Max. Temp.	Mean Min. Temp.	Relative Humidity	Inches Rainfall (6 Mos.)	
Bundaberg ...	83.2	65.4	70	31.3	76.6	55.3	68	11.0	42.3
Mackay	83.0	69.3	76	55.8	76.6	59.5	72	11.5	67.3
Ayr	86.8	68.9	70	34.9	81.4	59.4	64	6.8	41.7
Innisfail	84.8	69.5	82	113.3	79.7	61.5	80	29.3	142.6
Cairns	87.3	71.7	74	74.7	82.5	64.8	70	13.7	88.4

Latitudes: Bundaberg 25°, Mackay 21°, Ayr 19°, Innisfail 17°, Cairns 16°; (Hawaii is at 20° north latitude).

Although some cane had been laid flat by heavy winds, there was little evidence of split or shredded leaves such as result when strong winds are continuous. Some of the cane area suffers an occasional frost and cool nights often prevail throughout a large part of the region. Thus there is considerable evidence of banded chlorosis.

The cane lands are generally flat and there are but few hilly, rocky fields to be found.

In general, the better cane soils are well-drained, sandy, alluvial loams. They are quite loose and deep and are low in organic matter, but generally of good texture and well supplied with both phosphate and potash. There are practically no alkali soils and few that are calcareous. Some few alluvial clays tend to run together and bake after a heavy rain. There are two chief types: (1) the red volcanic soils which are quite deep, but have a low available moisture content; they tend to be quite acid and are low in organic matter; they have an ample supply of available phosphate but are deficient in nitrogen and potash; and (2) the alluvial soils which are wet, cold and poorly drained, overlying a high water table; they are deficient in nitrogen but well supplied with minerals.

In districts where irrigation is needed, there is apparently an adequate supply of water not far below the surface. In some districts this water carries too much salt, and at one place they are anticipating trouble from water with 60 grains per gallon because the salt is accumulating due to a poorly drained subsoil. At another center, where the underground water level is being lowered by heavy pumping, the salt content of the water is increasing from year to year.

Preparing for Planting: There are only two real large plantations in Queensland which operate heavy tractors and implements for preparing their land for planting. The average 40-acre farmer cannot afford such heavy equipment. He prepares his land for planting by plowing with single- or double-disc riding plows

pulled by small tractors in some cases, but generally by a team of horses. The soil is plowed to a depth of about 10 inches and all trash is plowed under. Notched discs or springs on the plow frame are used to hold the trash down to the ground, and various types of trash cutters are used before plowing. Where a tractor is available a grubber or subsoiler follows this disc plowing.

Fields that are to be planted are cut early (in August). The rotary hoe is then used, usually twice, to cut up the trash and stubble. This works to a depth of 4 inches on heavy soils and 7 inches on lighter soils. The chisel grubber, which works 10 to 12 inches deep, is also used. The land is then left for about 6 weeks to allow the trash to decompose. At this time it is a general practice to sow a legume crop. This may be the Mauritius bean, the giant cow pea, or the Poona pea (Vigna katiang). The seed is broadcast and covered either by another rotary hoeing or with a disc harrow, which operation also further chops up any undecomposed trash. Nothing further is done until the green manure crop is ready to turn under. The legume crop is plowed under about 12 inches deep. The land is then fallowed for another month or six weeks, and is then harrowed and planted (in April). From 3 to 5 plowings with intermediate harrowings are quite common when preparing land for planting between September and March.

There is a gentlemen's agreement not to plant cane in a field the same year it is cut. Hence about 25 per cent of the total cane acreage is planted to a legume green manure crop.

Planting: The planting season in the irrigated district is from March to May; in the unirrigated districts it is from May to July. The entire stalk is used for seed, being cut up into 10- to 12-inch seed pieces, planted in freshly opened deep furrows that are 4½ to 5 feet apart, spaced about 3 inches in the row, and covered 4 to 6 inches deep to assure contact with moist soil. We found no farm where top seed only was used for planting. In general, the stand of cane in plant fields appeared very thin, and it was felt that the use of body seed was the cause of this. Very little attention is paid to replanting and spotty stands are common.

Practically all farmers use some type of planting machine, which plants and covers 5 to 8 acres a day. The larger machines open the furrow as well, and some of them have fertilizer attachments.

Cane Varieties: The Australian sugar planter who plants a cane variety that is not on the approved list as laid down for his particular mill by the Cane Price Board is liable to a deduction of as much as $2.00 per ton from his payment for cane delivered from such variety. The reason for this "variety approval" is to get rid of canes that are susceptible to the prevalent cane diseases of the various sugar districts. The principal varieties grown and from which over 75 per cent of the sugar comes are Badila, M 1900, H. Q. 426, E. K. 28, D 1135, Q 813, and H. Q. 409.

The Bureau of Sugar Experiment Stations, in its standards for the selection of new cane varieties, emphasizes resistance to disease (especially gumming), an erect growth habit, a high sucrose content, and an ability to make full use of a six-months' growing season and be mature in 12 months. Major emphasis is placed on resistance to disease, and the various crosses are judged by the mass action of their progeny to the most serious disease of the district where they are grown. Recom-

mended as resistant to gumming, and for the dry, red, volcanic soils are POJ 2878, POJ 2725, Co. 290, POJ 234, Oramboo and Korpi; for the alluvial soils are Q 813, Oramboo, Korpi, POJ 2725, POJ 2878 and Co. 290 (the latter on poor lands only).

Since all mills eventually figure payment for their cane on the basis of its sugar content, greater emphasis is placed on a high-sucrose cane than on a cane which might make more total sugar but requires more cane per ton of sugar to do so.

Irrigation: Twenty per cent of the total sugar is grown with irrigation. The average cane yield per acre for irrigated lands is 36 tons as compared with an average of 19 tons for the whole of Queensland.

Small irrigation plants owned by individual farmers are the rule. Sub-artesian water is pumped from 4- to 6-inch "spears" that have been driven into water-bearing sand some 15 to 40 feet below the surface. About six of these "spears" are connected to a single pump. One large irrigation project pumps its water from an adjacent river supply. Some Diesel and some electrically driven pumps are used. There are also quite a number of "producer-gas" plants which use gas from wood-burning outfits to run the pumps. Storage reservoirs are an exception. Most of the land is flat and little fluming is noted.

The long-line system of distribution is generally used. Small pipes at the head of each line take the water from the level ditch. These pipes are removed after each irrigation to prevent damage to them by the cultivating implements. The lines appeared to be too long; some were over 900 feet in length and had had water running in them for six hours and it had not yet reached the ends. One man was handling 35 lines that were opened at one time. His daily coverage was estimated at about 20 acres and he was applying about 7 acre-inches per acre.

The first irrigation to plant cane is given on top of the seed in a deep furrow. After this furrow becomes filled with enough soil to hold the cane erect, the water is changed to a furrow between the lines. When irrigations are necessary the intervals may be as close as 10 to 15 days. However, one plantation reports that last year they applied only 8 rounds to plant cane, 6 to first ratoons, and 10 to second ratoons; they used an 8-inch irrigation at 3-week intervals, and the irrigator covered about 4 acres per day.

Fertilization: There is a wide variety of fertilizer practices. There is an almost unanimity of opposition to the use of large nitrogen applications which result in such rank, succulent growth that the cane will lodge, because lodged cane is very unpopular in Australia.

In the use of commercial fertilizers, the general practice is to apply a mixed fertilizer with the seed or immediately on ratoons and to follow with ammonium sulphate when the cane is knee-high. At most places this is applied by a single-row, animal-drawn machine with a vibrating type of hopper. This mixed fertilizer is primarily composed of meat packers' by-products, the P_2O_5 being largely organic.

A need for phosphate and potash on many of the alluvial soils has not been definitely shown, and it is rather difficult to justify the high phosphate content of the mixed fertilizers that are being used thereon, unless the reason be a political one.

Filter cake is generally used as fertilizer by the larger estates but there are few data to show its value.

Fig. 1. Irrigating two sides of the line in five months old Badila.

Fig. 2. Long-line irrigation in the Ayr district.

The use of molasses is confined to the large estates near the mills because the transportation to small outlying farms is too costly. Data from yield trials were not available but it is claimed that an 8-ton application of molasses has resulted in a 10-ton gain in cane tonnage. The molasses is applied hot and directly from trucks to the row middles of plant cane when the cane is about one foot high, and to ratoon fields right after harvest. It is worked into the soil with the rotary hoe and may be supplemented with a dressing of superphosphate. The molasses application is generally followed 2 months later with 200 pounds of ammonium sulphate, and with another 200 pounds of the same nitrogen salt at closing-in time.

In order to indicate the amounts of fertilizer applied per acre, we give a few specific practices that are used:

(*a*) 300 pounds of 2-17-8 followed by 300 pounds of ammonium sulphate; this furnishing about 69 pounds of nitrogen, 51 pounds of phosphoric acid, and 24 pounds of potash.

(*b*) 320 pounds of 5.2-16.1-0 followed by 600 pounds of ammonium sulphate in two applications; which would furnish 143 pounds of nitrogen and 52 pounds of phosphoric acid.

(*c*) 400 pounds of 3-12-16 followed by 300 pounds of ammonium sulphate; or 75 pounds of nitrogen, 48 pounds of phosphoric acid and 64 pounds of potash.

(*d*) 320 pounds of 11-7-2 only; (35 pounds of nitrogen, 22½ pounds of phosphoric acid, and 6½ pounds of potash).

(*e*) 300 pounds of 8-10.6-8 only; (24 pounds of nitrogen, 32 pounds of phosphoric acid, and 24 pounds of potash).

(*f*) 15 to 20 tons of green manure carrying perhaps 200 pounds of nitrogen plus 400 pounds of superphosphate; (80 pounds of phosphoric acid).

(*g*) 500 pounds of 1-17-7½ followed by 300 pounds of ammonium sulphate; (68 pounds of nitrogen, 85 pounds of phosphoric acid and 38 pounds of potash).

(*h*) 600 pounds of 7-10-10 followed by 300 pounds of ammonium sulphate; (105 pounds of nitrogen, 60 pounds of phosphoric acid and 60 pounds of potash).

Cultivation: Cultivation of plant cane is thorough and continuous until the crop is covered-in. Since the seed has been covered deeply, it is common practice to use the "spinner" directly on the cane row to remove a small amount of soil and the small weeds growing therein before the cane shoots are very far out of the ground. Sometimes the "spinner" is run twice in the cane row to clean out young weeds developing there. It requires considerable skill to run this spinner and avoid going too deeply and this work is generally done by the farmer himself. In addition to the spinner, the "cotton king" harrow and the "sun weeder" cane cleaner and cultivator are in general use for cleaning the cane line until the cane is a foot and a half high. At one farm cane that was three months old had had 3 cultivations; once with the harrow and twice with the cane cleaner. These implements are pulled by horses; few mules were in evidence, nor were there any small-type garden tractors used for motive power. Practically all cultivators are the walking types.

Fig. 3. The "spinner" removing soil and small weeds from the cane line.

Fig. 4. Cultivating plant cane with a six-tine grubber working about 12 inches deep.

This continuous use of cultivators is claimed to be necessary for weed control and to conserve moisture. A wide variety of tools for cultivating between the lines is found and every farmer seems to have a great many of them. The deep-tine grubber and the one- or two-horse cultivator, as well as a small rotary hoe with small moldboard to open a furrow for irrigation, are common. In spite of the extensive use of cultivators, it is necessary to do some hand hoeing in some fields. There is no question that weed growth in plant fields is at a minimum. The soils appear easy to work and plant cane looks generally vigorous, although the color is slightly yellow. The use of implements appears excessively frequent and deep. The amount of work that might be accomplished with these machines could be increased if they had riding attachments. It is rather hard to fit the high-priced labor policy into the scheme of cultivation that is found operating.

When cultivation of the plant crop is completed, the deep planting furrows have been filled and even slightly hilled-up. This may be one reason for the few ratoon crops they are able to take off; they do not average two ratoons, and it appears that much more attention is given to planting than to ratooning.

The cultivation of ratoons is accomplished after burning-off the trash or rolling it into alternate interspaces. Where the trash is burned, both long and cross harrowing with either disc or spike-tooth harrows are practiced. This operation, in addition to leveling off the field, mulching the surface and getting the early-started weeds, destroys the upper eyes of the cane stubble and forces the ratoon crop to develop from the lower eyes. This growth results in much larger sticks.

Cultivating implements for ratoons are set to work very close to the cane line. The rotary hoe and a grubber with two sets of three teeth that work 12 inches deep are in common use. Off-barring both sides of the line, and the use of the stubble shaver for cutting down stubble in irrigated fields, both find a place in ratoon cultivation. Much of this cultivation appears to be very destructive to the root system and certainly prevents the stool from widening out; and with all this implement cultivation ratoons need hand hoeing in the cane lines. Only about 30 per cent of the total crop in Australia comes from ratoons and in general there is a decreased yield of about 10 tons for each successive crop after the plant crop, e.g., the average yield of plant cane in one district is 50 tons per acre, of the first ratoon crop 40 tons, and of the second ratoon 30 tons. No root disease was evident. Some farmers get no ratoons at all; irrigated lands usually get at least two ratoons, but unirrigated lands average less than two.

Diseases: The principle of disease control in Australia is based on the selection of resistant varieties. They aim at control rather than eradication. This policy is apparently very successful, since many serious diseases are present, yet on the better farms disease was rather hard to find. Where it was found, however, the intensity of the infection, except mosaic, was very severe.

The following diseases were noted: Gumming, leaf scald, Fiji disease, downy mildew, chlorotic streak, dwarf disease (a new disease confined to a very limited area at present), and a cane-killing weed (striga)—a parasitic weed that gets into the rhizome of the cane and kills the stool.

It was of interest to note that mosaic disease is not widely spread in northern Queensland. The aphis that spreads mosaic was present but there was very little grass present for this host aphis to develop on. It is quite possible that either the

Fig. 5. Tractor-drawn rotary hoe for cultivating, with furrow opener to prepare lines for irrigating.

Fig. 6. Applying fertilizer. (The only mule we saw in Queensland.)

clean field culture or the frequent plowing and planting of cane may be the reason for mosaic not spreading in Australia, or perhaps some climatic factor may exist that is unfavorable to the spread of mosaic there.

Insects and Pests: The cane grower also has to contend with the cane root grubs, both the moth and the beetle borers, armyworms, wire worms, white ants, and rats. The first and last named of these pests are extremely destructive. By speeding up the rotary hoe, one plantation is apparently doing a lot of damage to the white grubs that are contacted. By an energetic rat campaign which includes poisoning, trapping and burning-off heavy vegetation that harbors the rat population, these animals are being somewhat controlled.

Harvesting: Plant cane is cut at 14 to 18 months, while ratoons are harvested ahead of plant crops at 10 to 12 months. The small farms harvest about 30 acres of their 40-acre assigned lands each year.

Most of the cane is cut unburned. This is because the mills are unable to control the delivery of burned cane within the 48-hour period after its cutting, that is desirable to prevent deterioration.

Very few of the cane farmers do their own harvesting, although they do perform most of the other field work connected with raising their cane crop. Consequently the harvesting work is left for a body of strictly seasonal laborers, a highly unionized group who work under very strict regulations.

These itinerant cane cutters work in small groups of 6 to 10 men each. They are required to cut, load, and lay portable track. In 25-ton cane they were averaging 4½ to 5½ tons a day; in 60-ton erect Badila cane they were making 7 tons a day. Hence the laborers produce a good day's work.

The full length cane stalks are loaded on crosswise and tied down with chains to small, steel-frame cars that weigh about 700 pounds and carry 2 tons each. These cars run on 24-inch track. When the main track line is too distant from the field these cane cars are hauled into the field on wagons that are fitted with rails on which the car rests and from which it may be rolled off onto the rails of the main line.

There are many specifications concerning the cane that the mill may accept from the grower. Cane with less than 7 per cent C.C.S., which is equivalent to a quality ratio of 14.3, is not accepted by the mills. Deductions in the price paid by the miller to the grower are made for burnt cane except when the cane was accidentally burned by the mill owner's locomotives or employees. A deduction may also be made for diseased cane and for cane that is not an approved variety. Cane with more than 3 per cent trash, tops, dirt, dry or rotten cane is not accepted and must be cleaned at the grower's expense.

A mechanical cane harvester was in operation at one of the larger plantations and it was doing a fair job of cutting and loading burned 25-ton, erect cane at the rate of about 10 tons per hour. Its future is problematical since the labor organizations are not especially interested in the development of machinery that may increase the list of unemployed.

Transportation: Cane is transported to the main line on portable track, on wagons, and by motor truck, by the farmer. On most farms the cane tonnage is too light to make the use of portable track in the field economical. There are but few derricks and hoists at the main lines to use in transferring cane to the railroad

Fig. 7. Sixty-ton Badila cane 18 months old.

Fig. 8. Harvesting unburned Badila cane.

cars. Hence, it is a common sight to see the loaded, small cane cars mounted on wagons being unloaded directly to the main track line.

Milling Practices: The method of unloading cane at the mills in Australia is by use of the Davis rake and the tilting platform on which the cane car is tipped and the load dumped onto the carrier. Thereafter a double set of levelling knives is used; the first set levels the cane, while the second set does most of the cutting.

Ninety per cent of the mills use National shredders. These prepare the cane for the diffusion process which is almost universally used. The use of these shredders and the fact that the mill is rigid makes it necessary to use pushers. The mill grooves have a 2-inch pitch. The mills are spaced as far apart as 60 feet, and it takes the cane about 20 minutes to travel through a Queensland mill. The diffusion baths are kept at a temperature of 180 degrees to 212 degrees F. Fifteen per cent of the total steam is used at this place. Twenty to twenty-two per cent imbibition water is used on the cane. Generally speaking the milling in Australia is costly.

Boilerhouse Work: Pipe lines are in general poorly insulated, resulting in considerable loss of heat. Short stacks make it necessary to use forced draft. The moisture in the bagasse runs from 44 to 52 per cent. Nearly all mills find it necessary to burn extra fuel, this is chiefly wood, but some coal is used. Most of the milling plants are very old. The Colonial Sugar Refining people particularly make a wide usage of instruments to measure work within the mills and spend a large part of their off-season time working up the data secured with these instruments.

Clarification: The Petree process which was formerly used has been abandoned. The C. S. R. subsiders are in general use and may be the reason for poor clarification, since the juices are not clear. Hot limed juices tend to have a pH of about 7.4. The subsiders are used to economize on presses, cloth, etc. The claim is made that a thicker mud is obtained than from the Dorr clarifiers. The mud from the subsiders is either sent to the fields or dumped into the rivers. All C.S.R. mills use double filter presses.

Evaporating: Syrups are evaporated to 72 Brix. Molasses is not diluted.

Boiling is done direct with live steam under a low steam pressure. There is evidence of molasses fermentation over the week end.

Pans: Coil pans are preferred, using exhaust steam at low pressures—5 to 6 pounds. It takes a long time to boil a strike—8 to 10 hours. There are some calandria pans in use.

Centrifugals: The centrifugals use steam for drying. The 48-inch machines are run at 850 r.p.m. from overhead belts which appear dangerous. These machines are bottomless and discharge when stopped.

Dryers: Practically all mills have taken the tubes out of their dryers and are using the dryers as coolers.

Bagging: Sugar is bagged in 160-pound bags which are closed by machines after filling.

By-Products: Molasses is used in the manufacture of alcohol, for fertilizer, and for stock feed, or it may be spread on the bagasse and burned. A mixture of gasoline and 15 per cent alcohol is marketed under the trade name of "Shellcoll."

Filter cake and mill ash are used as fertilizers or thrown away. The bagasse is all burned.

Fig. 9. Transportation of cane on small cane car mounted on a wagon.

Fig. 10. Modern quarters for cane cutting gang.

General: There is very little control in the milling practices, because other than weighing cane in and sugar out, few weights are taken. Thus the milling losses are undeterminable and the extraction figures only approximate. It was of interest to note that some of the laboratories were using the same laboratory forms they used 30 years ago.

Factories are steam or belt driven, none electrically driven although some parts may be. There are few safety devices in the mills, open gears and belts are common, and the amount of belting appears excessive. However, there are very few accidents in the mills which may probably be due to the high type of intelligence of the labor.

Conclusion: In conclusion, we must admit we found little in the Australian field practice that we feel can be adopted in Hawaii to help us grow cheaper sugar. Their preparation for planting appears to be excessively overdone, and we question the necessity of planting cane in deep furrows on the unirrigated lands. Their irrigation methods appear wasteful of water, and it would seem that there is room for larger cooperative pumping units to replace the many individual units now operating. Their fertilizer program needs to be differentiated on the basis of proven facts of their soil fertility needs, and when found, such facts need recognition. As with their preparation, cultivation also appears excessive, and poor stands, small stools, and failure of ratoons, all indicate that something may be wrong with their cultivation practices.

One comment was, "they worry the cane to death with their continuous use of implements." Another was that, "the machinery salesman must have found the Queensland sugar district a paradise in which to sell," and "since the farmer has bought all these implements, he feels that he must use them whether or not he needs to." Their harvesting is efficient but perhaps no more so than ours, and it is certainly more expensive.

Their cane farmers are not all happy and prosperous. Their homes are too often without the modern conveniences of running water and sanitary facilities. Few own automobiles, and recreational facilities except the race tracks are sadly lacking. Their highly paid laborers are always "broke" after their week end in town. They live in very unattractive barracks on the farms. The high standard of living these laborers enjoy was not prominently demonstrated unless the Saturday night crowd in the "pubs" exemplifies this high living.

The fact that the elaborate system of government control does not obviate expensive strikes (labor troubles) was well illustrated by the strike of cane cutters in progress as we visited the Tully district; hundreds of cars of loaded cane were left rotting in the mill yard while the government refused to step in and settle the illegally called and prolonged strike that was on. Likewise we note that the government's 1929 attempt to restrict the sugar crop to the domestic market has not reduced production, as seen by the fact that their 1934 crop was nearly 20 per cent larger than their 1929 or the 1930 crop.

Hence, other than their policy and practice for controlling cane diseases, which appears economically sound and definitely effective, the Australian sugar industry has little that the Hawaiian sugar planter might adopt in his efforts to grow cheaper sugar.

Growth-Failure Problems

By A. J. Mangelsdorf

The so-called growth-failure areas on our plantations merit attention not only because of the loss in sugar yield which they entail but especially because they may represent in an exaggerated form the effects of plant food deficiencies, of toxins, or of other depressing factors which are acting upon larger areas in a less pronounced degree. As such, they provide research material for a study of growth factors which might prove elusive under more nearly normal conditions.

Such interest is not necessarily applicable to all areas of poor cane growth. Many of the poor-growth spots are of local significance only. An example of the latter type is the growth failure in Fields Mill 3 and 5, Waialua, found by J. P. Martin* to be due to the shallowness of the soil overlying an irregular stratum of coral rock. Similar examples of growth failure due to shallow soil and rock outcroppings may be found at Ewa; in the island fields of Oahu Sugar Company, Ltd., and in the Puuloa fields of Honolulu Plantation Company.

Other growth-failure spots of local significance only are the following:

1. Small areas of poor growth at Kilauea, on spots where carloads of coral sand were dumped in past years.

2. Areas of poor growth due to high salt content, such as the saline spots near the sea at Kekaha; in the Puuloa fields of Honolulu Plantation Company; and in the makai fields of Olowalu Section, Pioneer Mill Company, Ltd.

3. Gravelly areas of low moisture-holding capacity in certain of the Olowalu fields of Pioneer Mill Company, Ltd.; and at the Mapulehu Station on Molokai.

4. Coral chlorosis areas. The problem of supplying iron as a soil amendment remains unsolved. A trial of briquettes containing iron salts has been suggested.

Other growth-failure areas, the causes of which have not been fully established, and which therefore demand further attention include the following:

1. Areas of relatively poor growth in the older mauka lands of McBryde and Makaweli as contrasted with the superior growth on immediately adjoining virgin land which has recently been added to the field. Studies of the differences between closely adjoining areas of new and old land would appear to offer particular interest. Such studies might be expected to throw light on the cumulative effect, if any, of years of irrigation, fertilization, and cropping and perhaps to forecast further changes to be expected as cropping is continued. While it is true that the yields in sugar per acre per month over the Territory as a whole have been increasing, the superior growth of cane on new lands as at McBryde and Makaweli serves to remind us that the improvement in yields realized in the past does not establish the absence of a downward trend in one or more of the essential growth factors, but merely that improvements in other respects have more than offset the effect of such downward trends if they exist.

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* *The Hawaiian Planters' Record*, Vol. XXXII, 1928, pp. 406-411.

It is to be expected that in the course of time a limit will be reached in the gains to be effected by improved agricultural practices and more vigorous cane varieties. Considerable interest therefore lies in the question of whether the soil is being impaired in any way, and if so, how the impairment is to be met. Investigations comparing the cane and the soils of adjoining areas of new and old land would appear to offer a promising approach to this problem. What differences, for example, are to be found between the old and the new lands in available P and K and in the other essential elements? What has been the effect on the colloidal fraction of years of irrigation at a rate equivalent to one or two hundred inches of rainfall a year?

2. The Maui "H 109 Growth-Failure Areas." These areas have received considerable attention during the past five years. In cooperation with Hawaiian Commercial & Sugar Co., Ltd., O. H. Lyman has carried out a number of pot tests with indicator plants in which many soil amendments have been tried. Treatments which gave indications of benefit were subsequently tried on affected cane in the field.

The treatments have included nitrogen, potash, and phosphorus in various forms and amounts as well as such soil amendments as molasses, press cake, agricultural lime, chloropicrin, sulphur, portland cement, barium chloride, copper sulphate, manganous sulphate, ferrous sulphate, calcium chloride, potassium iodide, sodium borate, potassium bromide, zinc sulphate, pyrogallol, and silica (waterglass).

Heavy applications of phosphate have resulted in improved growth in the pot tests, in spite of the fact that available P as determined by kit and citric soluble analyses is higher in the growth-failure areas than in the normal soils. This suggests a possibility that the phosphate applications exert their effect indirectly, perhaps by precipitating some toxic material, such as aluminum.

In 1925 W. T. McGeorge found evidence of iron or aluminum accumulations in cane from Maui growth-failure areas, but subsequent studies by him in 1926 failed to substantiate his original findings.

In 1934 D. A. Cooke conducted a study of normal and growth-failure soils from Field 2-G, Co. 9, Hawaiian Commercial & Sugar Company, Ltd. His findings indicated that active aluminum is responsible for the growth-failure, and that the beneficial effect of applications of phosphate and filter cake are due to the action of these materials in converting toxic aluminum to insoluble and harmless forms.

The results of analyses of these soils by the Chemistry department are tabulated below. The figures show that while P_2O_5 is higher in the growth-failure soils than in the normal soils, aluminum is also higher. The high alkalinity of the growth-failure subsoil is characteristic of such areas.

It has been suggested that magnesium toxicity, or high magnesium in proportion to calcium may be responsible for the Maui growth-failure symptoms. These analyses, however, are not in agreement with this hypothesis.

HAWAIIAN COMMERCIAL & SUGAR CO., LTD.

(Field 2G, Co. 9)

(Results calculated to water-free basis)

Lab. No.	Mitsch. No.	Reaction pH	1% Citric Acid Soluble SiO_2	CaO	K_2O	P_2O_5	Fe_2O_3	MnO_2	Al
Growth-failure—first foot									
623	1211	8.1	1.550	0.824	.1279	.0481	1.051	0.100	.394
Growth-failure—second foot									
624	1212	8.8	2.482	1.155	.1241	.0414	1.338	0.105	.520
Normal—first foot									
625	1213	8.1	0.822	0.508	.1033	.0144	0.520	0.149	.268
Normal—second foot									
626	1214	7.8	0.643	0.489	.0806	.0177	0.374	0.113	.273

Lab. No.	Mitsch. No.	Replaceable CaO	MgO	Na	Water Sol. Solids	Kit P_2O_5	P_2O_5 Fixation Index
Growth-failure—first foot							
623	1211	.242	.130	.089	.072	High	10
Growth-failure—second foot							
624	1212	.344	.086	.061	.106	High	0
Normal—first foot							
625	1213	.248	.164	.087	.075	High	30
Normal—second foot							
626	1214	.262	.153	.085	.097	High	40

Mr. Cooke's suggestion that the Maui growth-failure symptoms are due to aluminum toxicity would appear to merit further investigation. It would be of particular interest to determine whether the chlorotic leaf streaking which characterizes the cane in growth-failure areas can be induced on cane plants in pot cultures by additions of aluminates to normal soil under alkaline conditions.

The following is an excerpt from Mr. Lyman's annual report for 1934:

One pot test with H 109 growth-failure soil was carried on cooperatively with Maui Agricultural Company and Hawaiian Commercial and Sugar Company. In this test, growth-failure soil was diluted with good soil ranging from 0 to 100 per cent with 25 per cent increments. Surface and subsoils were run separately. Practically no difference was found in the yields from surface or subsoil, but with both when the better soil was added, the yield was heavier. From these results we believe the problem has been narrowed down to either a lack of some plant food or an oversupply of a toxic substance in the soil.

Several tests were made with iron sulphate spray on growth-failure cane in Field 19 at Hawaiian Commercial and Sugar Company. One area produced a decided greening from the iron application but subsequent spraying on nearby areas revealed no greening from this addition.

Repeated tests with factory mud have shown definite and good response in growth-failure areas. So far this is the only material of any kind that has produced a response in this field. We are now cooperating with the Chemistry department with the hope of determining just what it is in the mud that produces this response.

Mr. Lyman discusses the present status of the problem in a recent report to R. J. Borden as follows:

In reply to your memorandum concerning growth failure on Maui, project A-103, our studies have been limited to the special type commonly known as "H 109 growth-failure," confined entirely to H. C. & S. Co. and M. A. Co. and chiefly to the former. Other growth-failure areas on the Island are of minor importance or may be described as gravel pockets or have some obvious cause. These will not be taken up in this report, where we will confine ourselves to "the H 109 growth-failure" areas located in Central Maui.

Characteristics of the Malady

The first appearance of the malady is an irregular chlorosis of the central portion of the leaf. In the early stages or in mild cases the outer edges will retain their green color. More severe cases become chlorotic throughout. Brown stripe disease is usually found in great abundance showing the most marked infection on the older lands. Cane grown on failure spots in virgin soil is relatively less susceptible to brown stripe than on the older areas. The failure symptoms may first appear in knee-high cane, cane in the boom stage, or not until the crop is partially matured.

Stunting of the entire plant follows the first symptoms and in extreme cases the stool will die out entirely. Stools may be pulled out of the ground with ease, exposing roots badly diseased and some entirely decayed. *Pythium* has been found by our pathologists but is usually considered as a secondary infection.

Soil Characteristics

Generally speaking, in old lands little difference may be found in the physical appearance or chemical composition of the soil in the failure areas when compared to good areas in close proximation. However, in virgin lands where a dark purplish subsoil is found close to the surface, the growth-failure malady is found to accompany it. Also in areas where a peculiar whitish-grey rotten rock is found outcropping, the disease may usually be found.

Work Done So Far In Search of a Remedy

Chemical analysis, pot work, and field experimentation have been carried on on a large scale for many years in an endeavor to locate some clue that might give us a remedy. To date but two lines of attack appear successful, i. e., factory mud applications and more resistant varieties. Factory mud has given marked responses where all other soil amendments failed. Complete analyses are now under way in an effort to determine the exact composition of this material so that we may find the single ingredient or series of ingredients that will satisfy the requirements, i. e., either precipitate the toxins or supply some deficiency that growth may be maintained.

From the variety standpoint the very leafy vigorous canes appear to withstand the malady. In recent harvests Co. 290 and 28-4314 have proved the most resistant. 30-2417 although not as extensively tested as the two previously mentioned, appears promising.

Increase or Decrease in Extent of Areas

There has been much discussion as to the possible increase or decrease in the size of the individual growth-failure areas. A great deal of time was spent in cooperation with the plantation civil engineering department of H. C. & S. Co. to obtain definite information on this controversial question. All of the fields which today are known to possess areas of this malady were studied in detail as far back as 1909 and 1910. It was found that in most cases when a field was planted the entire area was plowed up and planted to cane. When these failure spots became evident they were culled out, dropped from cultivation, and the location and area recorded on the original map in the engineer's office. At the start of each succeeding crop the field was subjected to this procedure and as a consequence we have a record of the areas discarded for many years back.

It must be remembered, however, that these areas removed from cultivation contained gravel pockets, sand pits, etc., in addition to the typical "H 109 growth-failure areas." But should the "H 109 growth-failure areas" be slowly increasing in area many of these spots would be recorded as gradually increasing in size over the period of time (25 years) in which the study was made and today would have reached a size much greater than that originally recorded. This, however, cannot be found on the maps. A few areas have increased in size, others have decreased, and still others have disappeared entirely. We therefore could find no proof that the areas are definitely becoming larger.

From the personal observation of the writer during the past seven years, certain fields which have shown marked infection in the plant crop, have produced a decreased degree of infection as crops go on in that planting cycle; other fields show that new areas have sprung up which were never before known to the oldest man on the place; others have maintained uniform size not varying from crop to crop; and still others have increased in size from time to time.

Records of the exact location and extent of these areas are still being continued by the engineering departments of both H. C. & S. Co. and M. A. Co.

The tolerance of Co. 290 and certain other seedlings for the growth-failure condition is of interest from the plantation standpoint, but it throws no light on the cause of the failure in the case of H 109.

As Mr. Lyman has suggested, the effectiveness of press cake in correcting the difficulty should provide clues which may lead to an understanding of the underlying causes; these clues need to be pursued further.

3. Hamakua Growth-Failure. The interest in the low-yielding fields of mauka Kukaiau (Hamakua Mill Company) finds justification in the premise that if ways and means can be found to improve the yields of these fields the findings may have rather wide applicability in the mauka lands of the Hilo, Hamakua, and Kohala districts.

Under the late Y. Kutsunai's supervision the problem was attacked from many angles. Mr. Kutsunai's daily reports (Project File 452.11) give detailed accounts of the various phases of the investigation. Summaries of the work appear in the annual reports of the Agricultural department for 1933 and 1934. The subjects to which attention was given included the following:

1. Phosphate fixation.
2. Loss of nitrogen and potash by leaching.
3. Moisture-holding capacity of the soil.
4. *Pythium* injury to the roots.
5. Accumulation of iron and aluminum at the nodes.
6. Amounts and forms of N, P, and K.
7. Methods of applying N, P, and K.
8. Effects of other essential elements and of various soil amendments.

The findings may be summarized as follows:

1. The growth-failure soils were found to be low in available P and K.
2. Phosphate fixation, at first believed to be extremely high, now proves to be only moderately high.
3. Potash and nitrate nitrogen are readily leached.
4. Moisture equivalent determinations have given anomalous results, and require further study.

5. *Pythium* injury to the roots was shown to be an important depressing factor in pot studies on these soils. Heavy applications of phosphate, even in the presence of *Pythium,* resulted in normal growth in the pots. Are the severe *Pythium* damage and its amelioration by applications of phosphate peculiar to pot cultures as contrasted with cane growing in the field? (The tremendous responses to phosphate regularly obtained in pot tests with canes as well as with Sudan grass have not been realized from cane growing in the field.)

6. Accumulations of iron and aluminum were found at the nodes of cane plants from the affected areas. What importance is to be attached to these accumulations?

7. Except for N, P, and K, cane leaf compost (heavily fertilized with N, P, and K during composting) and stable manure, none of the soil amendments has proved effective in improving cane growth.

A possible exception to the above is lime. Recent pot tests on Sudan grass growing in the Hamakua soils show response to calcium. Is Sudan grass a lime-loving plant as compared with sugar cane?

The most satisfactory cane growth attained thus far on these poor soils is to be seen in an observation test in Field 27 Kukaiau (Indicator Test No. 39). The variety is 28-4291, a Uba-H 456 seedling which has been among the leaders at the Hamakua Mauka Variety Station. Various amounts of N, P, and K were tried on small plots of this seedling. Of the three elements, nitrogen appears to have been the most effective, a marked response having resulted from a 500-pound application of N. Heavy phosphate applications in addition to the 500 pounds of nitrogen resulted in further gains.

The growth response in this observation test suggested to Mr. Kutsunai the desirability of a replicated experiment to determine the ability of 28-4291 to respond to various amounts of N, P, and K. Shortly before his death he arranged for the planting of a seed nursery of 28-4291 at Paauilo for the purpose of obtaining planting material for the installation of further fertilizer tests on this variety in an abandoned growth-failure portion of Field 27 Kukaiau. These tests are now under way.

The mauka lands of Honokaa which formerly gave poor yields have been brought to a satisfactory level of productivity. H. P. Agee suggests a comparative study by rapid chemical methods of Kukaiau versus Honokaa soils to determine the differences, if any, between the two. Mr. Borden suggests further that virgin uncultivated soils of each series be included in the study.

It would seem desirable to compare the Honokaa and Kukaiau soils in pot tests also, on the chance that there may be differences between the two which might escape detection by chemical methods.

4. Areas of poor growth on the upper lands of windward Kauai. Mention has already been made of small growth-failure spots at Kilauea where carloads of coral sand had been dumped in the past. Greater interest, however, attaches to the more extensive areas of unsatisfactory growth on the middle and upper lands of the windward plantations. The cane on these poor areas is characterized by freckled, chlorotic leaves and by severe brown stripe infection. Apparently, however, these are merely symptoms rather than causes of the poor growth.

In 1932 Arthur Ayres investigated the soils of some of the poor mauka fields on windward Kauai. He describes these soils as follows:

1. Surface soil shallow.
2. Lime content low, magnesium probably also low.
3. Reaction moderately to highly acid.
4. Low in phosphate, potash, and silica.
5. Phosphate fixation high.
6. Subsoil highly acid and infertile.

As regards climate, the Kauai growth-failure areas have nothing in common with the "H 109 growth-failure areas" of central Maui, yet they are both marked by severe brown stripe infection, a circumstance which suggests that these two widely different soil types may have some toxic element in common. The fact that they both respond to phosphate applications in pot cultures emphasizes their relationship. Do phosphate applications exert their beneficial effect on both of these soils by precipitating toxic aluminum and rendering it inactive?

Dr. Constance Hartt has recently grown plants in cultures lacking magnesium. These plants show leaf symptoms closely resembling the Kauai growth-failure symptoms except for the absence of brown stripe, due perhaps to the absence of sources of infection.

Observation tests with magnesium sulphate were suggested by W. W. G. Moir in 1931 and several tests were subsequently installed in the Makee Section. On the whole, the response in cane growth in these tests was not definite. Nevertheless, it would seem desirable to repeat tests of a similar nature on the growth-failure areas using magnesium, alone and in combination with calcium in varying proportions.

Whatever the causal factors may be, these growth-failure areas with their high incidence of brown stripe present an interesting riddle—one which thus far has defied the many attempts to solve it, and which for that reason offers a tempting challenge to the investigator.

Summary

1. The so-called growth-failure areas are of special interest as subjects for research because they may represent in an exaggerated form the effects of depressing factors which are active in a milder degree over large areas and which, in their milder manifestations, may elude analysis.

2. Among the problems related to growth failure which still remain to be solved are the following:

a. What factors are responsible for the superior growth of cane frequently noted on virgin lands which have been recently added to old fields by extending their boundaries?

b. How can iron best be supplied to chlorotic cane on alkaline coral soils?

c. New varieties having a high degree of tolerance for both the Maui and the Hawaii growth-failure areas are now available. What are the deleterious factors to which these varieties are resistant and what is the nature of their resistance?

d. What factors are responsible for the high incidence of brown stripe disease on the growth-failure area of windward Kauai?

The work which has already been done on the growth-failure soils has added a great deal of information, but the underlying causes of the poor growth on these soils are not yet fully understood.

Irrigation Labor Requirements and Fixed Charges

By W. W. G. Moir

During the last few years considerable interest has been shown in the reduction of labor requirements for irrigation. The reports of the Hawaiian Sugar Planters' Association and the Association of Hawaiian Sugar Technologists have shown the various changes that have been made in irrigation procedure to speed up irrigating and lower costs. The newer systems have greatly increased the area per man-day covered in irrigating. Most of these newer systems have been developed on slightly sloping or fairly flat lands, where the grades of the cane line and the supply ditches or level ditches have been such that speed could be attained without excessive erosion or decreased growth of cane. The steeper slopes, however, have been left in the old contour systems or the various improvements of it, such as the Koloa system, the hulihuli or others. These improvements of the contour system, even to the long-line contour have not attained the acreage per man-day that has been obtained on the border and straight-line systems of the slighter slopes and flat lands. This has been due entirely to the size of the stream that could be brought down the steeper grades to feed these lines. Watercourses, straight ditches, wing ditches, or even the zigzag "level" ditches of the Pioneer system were subject to too much erosion whenever the rate of irrigating was increased by using larger volumes of water.

To correct this drawback and to put these steeper slopes on an equal footing with the other lands, a number of plantations have developed systems using permanent or semi-permanent installations. These have taken care of all erosion and have permitted the irrigator to cover as much as, or more than, the area per man-day obtained on the slighter slopes with the long-line or the border systems. These permanent or semi-permanent installations have been of various types, such as: the wooden structures of the Baldwin* flume type, the concrete flumes and ditches of a semi-permanent nature like that at Waialua, the permanent ditches of rubble or cut stone and concrete, the cocnrete pipe and straight ditches at Pioneer, and several others.

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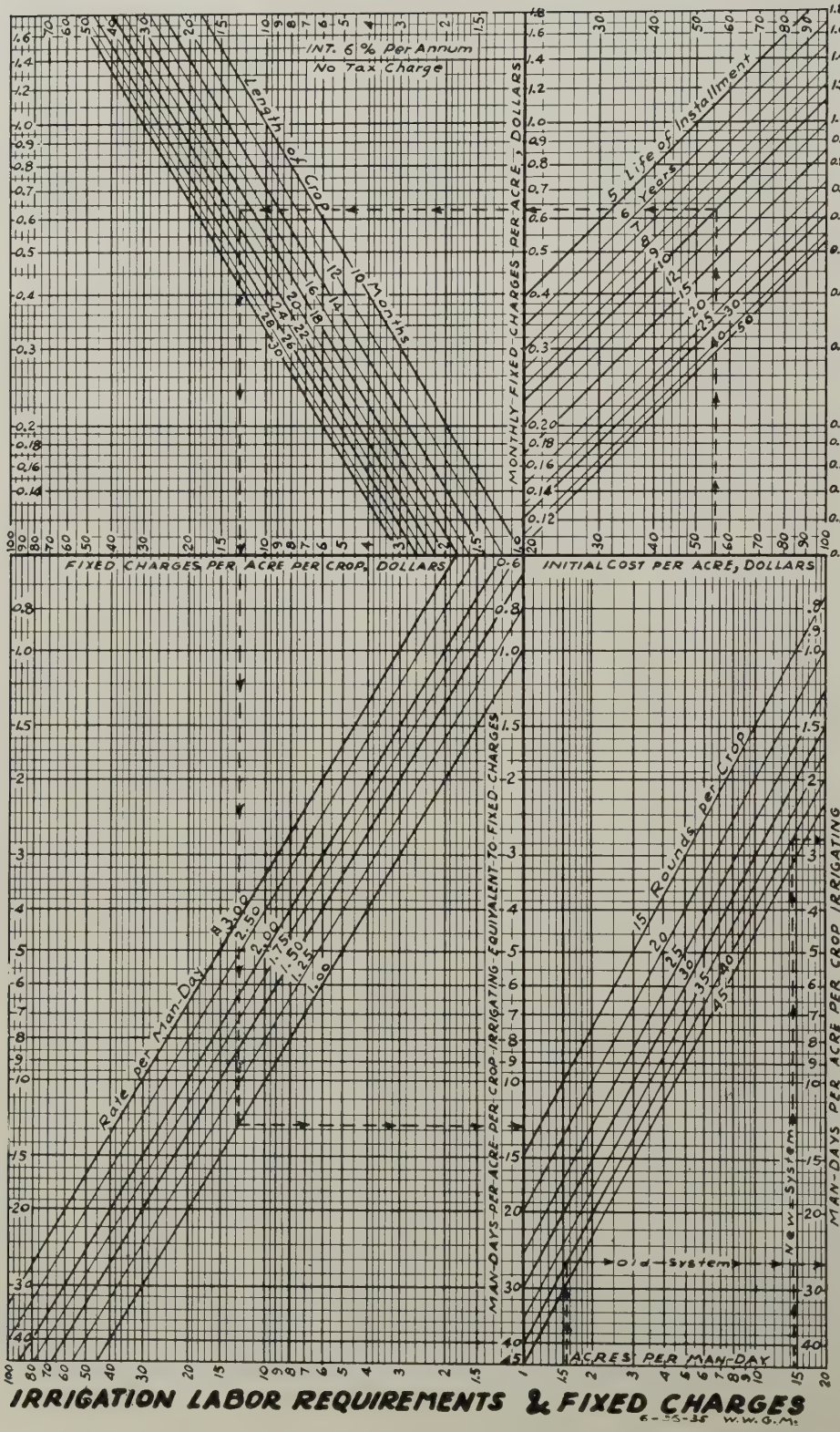
* Mr. Washburn Baldwin has recently developed a new type of concrete flume, a model of which may be seen at the Experiment Station.



IRRIGATION LABOR REQUIREMENTS & FIXED CHARGES

6-25-35 W.W.G.M.

It is only natural, therefore, that before such permanent or semi-permanent installations are made the various factors in each cane field which would influence the economy of making the installation should be studied. The amount that can be expended upon the initial installation will be dependent upon many factors. In this article, however, the matter of fixed charges resulting from the interest on the money invested and the depreciation of the structure are utilized to draw up a chart which may be useful to field men in their study of the particular installation contemplated. Taxes and insurance are not considered in these figures as they are too variable and would complicate the problem.

Therefore, the various factors entering the problem of whether the installation will be economical or not are, besides the initial cost, as follows:

1. The life of the installation or years in which it will be depreciated on the books.
2. The monthly fixed charges at 6 per cent interest on the money invested computed from the depreciation taken on the installation and the initial cost.
3. The length of crop in months.
4. The basic wage you expect your irrigator to make in the field.
5. The average acres per man-day required to irrigate the present system and what will be expected on the new.
6. The number of rounds of irrigation in the field for the crop.

The life of the installation will be dependent upon the material used, the length of lease on the land if not fee simple, the governmental tax rulings and the chances of the system becoming obsolete.

The fixed charges will be figured on the initial cost, the rate of interest per annum and life of the unit. As mentioned above, the taxes and insurance are not included here. The various formulae and calculations used in setting up the chart as far as fixed charges are concerned are explained herewith:

P—initial cost of installation per acre.
R—rate of interest per annum (6 per cent in this case).
n—life of the installation.

(1) Interest $= P \times R$

(2) Annual depreciation $= P\left[\frac{R}{(1+R)^n - 1}\right]$

Therefore, without taxes, insurance, rent, etc., the annual fixed charges would be the sum of (1) and (2).

(3) Annual fixed charges $= PR + P\left[\frac{R}{(1+R)^n - 1}\right]$ which equals

$$P\left[\frac{R}{1-\left(\frac{1}{1+R}\right)^n}\right]$$

The monthly fixed charges used in the chart are one-twelfth of the annual charge.

In the chart the initial costs have been varied from $20.00 to $100.00 per acre and the life of the installation from five to fifty years. It is quite conceivable that these figures may be more or less than those used, but these were decided upon as

covering the average condition. There are conditions, however, in which an initial cost as high as $150.00 per acre might become economically worthwhile.

The other items in the chart have been varied as follows:

Monthly fixed charges	$0.10 to $1.80
Length of crop	10 to 30 months
Crop fixed charges	$1.00 to $100.00
Basic wage	$1.00 to $3.00 per day
Rounds of irrigation	15 to 45
Acres per man-day	1 to 20
Man-days per acre per crop and Man-days per crop equivalent to fixed charges	0.6 to 4.5

Most of these are clear enough without any further explanation. The basic wage item, however, is a figure obtained by considering the irrigation contract rate, the cane tonnage per acre and the days worked in the contract. In many of these newer systems the rate has been lowered because of greater coverage per man-day and because weeding has been eliminated from the work performed by the irrigator. The example used of $1.00 per day is very low considering the average of all plantations but the figure was used to show an extreme number of days that would have to be saved to be equivalent to the fixed charges per crop.

As a means of explaining the working of the chart, let us follow the dotted line given as an example on the chart. The data used are:

Initial cost per acre	$56.00
Life of installation	10 years
Length of crop	20 months
Rate of wage per man-day	$1.00
Rounds per crop	40
Acres per man-day old system	1.55
Acres per man-day new system	14.5

Beginning on the lower edge of the upper right section of the chart with the figure $56.00, follow the dotted line to where it intersects the oblique 10-year line, then proceed at right angles to the left until the dotted line crosses the vertical scale. Here you can read the figure representing the monthly fixed charges per acre which, for this example, is $0.63+ per acre per month.

Continuing on the same dotted line to the left to where it intersects the oblique length of crop line representing 20 months and then at right angles down the chart to the horizontal scale, you obtain the fixed charges per acre per crop, which is approximately $12.60 in the example.

Proceeding on into the lower left section of the chart with the dotted line to its intersection with the oblique $1.00-per-day line and at right angles to the right to the vertical scale, we obtain the man-days per acre per crop equivalent to the fixed charges, which is 12.6 men. As mentioned above, the $1.00 per day is low and shows an extreme number of men necessary to be equivalent to the fixed charges. This represents the number of man-days that must be saved during the crop to at least pay for these fixed charges on the installation.

To see how your present irrigation system and the new one contemplated would allow for such a saving, we start again in the lower right section with the acres per

man-day covered in irrigation. The old system starting with its 1.55 acres per man-day and going up to the oblique 40-rounds line, and then to the right, shows that it would require just under 26 man-days to irrigate the crop. The newer system with its 14.5 acres per man-day and the same 40 rounds would require but a little over 2.75 man-days to complete the crop, as is shown by following the other dotted line starting at 14.5 going up to 40 and across to the right.

The difference between the 26 and the 2.75 man-days per acre per crop would be sufficiently great to fully cover the equivalent man-days per acre per crop for fixed charges of 12.6 obtained in the other three sections of the chart and which has been explained above.

By changing the daily wage to $1.50 and the rounds to 15 per crop and leaving all other things the same, the fixed charges per crop in equivalent man-days would equal the difference between the new and old systems on 15 rounds.

By increasing the daily wage the irrigator is expected to make the equivalnt man-days to pay for the fixed charges decreases. But other factors must change as well to keep the final cost of sugar per ton from increasing. But in the future, if labor becomes scarcer or more costly, these permanent installations will show even greater savings.

It must be remembered at this point that these are purely the considerations for the payment of the fixed charges due to the initial cost as explained above. Naturally, with increased coverage per acre per man-day the labor requirements of the plantation for irrigation purposes will be decreased and this will have its reducing effect on overhead charges for housing, hospitalization, etc.

Almost any section of this chart can be utilized separately to obtain necessary information about other operations on the plantation. The upper right-hand section can show you the fixed charges per month on almost any type of structure at the various costs per unit and per years of depreciation.

The lower right-hand section can show you just how little an increase in acreage covered per man-day will give a very substantial decrease in costs of irrigating the crop.

All spacings and lines have been made on a logarithmic scale, so, when determining the approximate reading, judge the space accordingly. By a study of the spacings on the various scales of the chart, you may readily get an idea of how to divide up spaces when necessary.

The writer is indebted to John Okamoto, of the Engineering Department of American Factors, Limited, for the assistance rendered in making the necessary computations and setting up the chart.

Investigations on *Anomala Orientalis* Waterhouse at Oahu Sugar Company, Ltd.

By F. A. Bianchi

The Asiatic beetle, *Anomala orientalis* Waterhouse, was probably introduced into Hawaii from Japan at some time prior to 1908. This beetle is not known as a pest of sugar cane in its native habitat, and in Connecticut where it has also been introduced, is found exclusively as an inhabitant and destroyer of lawns; but in Hawaii it has established itself as one of sugar cane's most important enemies. Although not yet spread to any other island than Oahu, and found here only over a relatively small area of 14,000 or 16,000 acres, the ravages of Anomala have at times been so serious as to cause the taking of extensive measures to combat it.

Many thousands of dollars were spent in devising means of artificial control and in seeking effective parasites during the early years of Anomala's spread, but without success. Finally, in 1916 and 1917, relief followed the introduction of a parasite. This parasite, *Scolia manilae* Ashmead, the wasp now so well known to plantation men, was at that time introduced from the Philippine Islands with such pronounced results that shortly after its introduction grubs and beetles actually became difficult to find in the previously heavily infested areas, and, with the exception of one or two minor cases, no further damage to cane was reported until early in 1930. At that time the harvest in two different fields of the Oahu Sugar Company, Ltd., again showed a considerable drop in production, attributable only to damage done by Anomala larvae which were to be found in the soil in greater numbers than at any time since the introduction of *Scolia manilae*.

For some time entomologists were of the opinion that the renewed abundance of the beetle might represent one of the occasional outbreaks, usually of short duration, which can be expected even under the best conditions of biological control. Eventually, however, when following harvests disclosed other limited areas of severe damage and a generally greater abundance of *Anomala orientalis* than had been usual for several years, it became evident that a careful investigation of the increase of the beetle was necessary, as it must have been due to a more permanent disturbance of the balance of pest and parasite than was to be expected under the usual course of nature. Subsequently, the conduct of that investigation became one of the major projects of the Entomology department of the Experiment Station, H.S.P.A.; and to facilitate much of the necessary work, the writer was detailed to take up permanent residence on the plantation of the Oahu Sugar Company, Ltd., there to devote full time to the study of the problem.

In the opinion of entomologists, one aspect of the problem involved a careful study, with an eye to possible reappraisal, of the biological factors of the Scolia-Anomala complex; a study which heretofore had only been carried on in a more or less desultory manner. To that part of the work then, the writer mainly directed his efforts and although the many ramifications of the problem will require much more thorough and lengthy investigation than has yet been given, it is hoped that the

results presented here will not prove entirely without value or interest to plantation men and other workers along the same line.

Life History of Anomala in the Field

It is hardly possible to determine accurately how well figures obtained in the laboratory represent the life cycle of Anomala in the field. A repetition, of certain general tendencies observed in the laboratory, towards a wide range of variation in larval life lengths, and towards a shortening of the life cycle during the warmer months of the year for example, is to be expected, and as a matter of fact is shown by all our observations; but the nature of the infestations makes it impossible to accumulate unmistakable quantitative data in corroboration of these and other points. The work so far done on the problem, however, gives us a satisfactory working outline of the picture, only the details of which are apt to be modified by further study.

Oviposition:

Under the usual field conditions, where the soil surface is dry and all but the upper layer is more or less packed, oviposition may occur at any depth to 18 inches, but eggs thus scattered through several inches of soil are so hard to find as to lead to the conclusion that because of difficulty experienced by beetles in ovipositing in hard soil, or because of great natural mortality of the eggs themselves in such a medium, they are actually scarce. Because of this scarcity it has been impossible to gather sufficient quantitative data to determine just how oviposition is distributed through this zone, but the impression that one gets in the absence of trash or mud press mats providing ideal conditions near the surface, is that most eggs are to be found between 6 and 12 inches deep, being much scarcer at lower soil levels. In recently harvested fields, however, it often happens as a result of poor "burns" that large areas of the field remain covered with a mat of cane trash and, if rainfall at the time is sufficient to keep the trash from drying out too much, oviposition seems to become concentrated at the point of contact of soil and trash. Eggs then are easily found and, apparently at least, are far more abundant than under ordinary conditions. Concentration of oviposition is also an ordinary occurrence in and under the crust of mud press which forms over the surface of the soil in fields where this material is sluiced on as fertilizer in irrigation water. In these cases accumulations of eggs are likely to be short-lived among the cane itself, because of their early destruction by the various processes of cultivation, but they often last long enough to produce a good many beetles in the various sorts of ditches, with which every field is provided, where mud press settles in large amounts and may remain undisturbed for weeks at a time.

A point which has not been determined is whether or not accumulations of eggs occur partly in consequence of some special attraction of trash and mud press for the ovipositing beetles or solely as a result of favorable conditions which cause a larger proportion of egg survival than is usual; but the latter of these explanations appears to be the more reasonable one, as beetles are very often found burrowing into dry soil, often in dry ditch bottoms, in evident disdain of more propitious locations within the immediate vicinity.

One might be inclined to believe that more eggs are found among or near the cane stools than between rows, but this is not necessarily the case. That eggs and grubs are more often looked for near the cane stools is true; but, as a matter of fact, the occasional trash accumulations under which they reach the maximum abundance lie very often between the rows, i. e., in the *pali pali,* or raked up trash.

All our observations show that mating and oviposition take place within a small radius of the point where the female beetle emerges. Distinctly fresh females carrying a full complement of eggs, and either single or in copulo, are very often found on the surface of the soil or among trash, but only within crawling distance of infested stools. Beyond this distance neither the writer nor anyone he has heard of has ever found them, either crawling or flying; all those so found, or feeding on flowers, being old, and retaining only a part, if any, of their original egg supply. A single example, from among the many records upon which this conclusion is based, shows that out of a total of 126 adult females caught on flowers by O. H. Swezey on May 2 and 6 of 1913, 123 contained no eggs at all, 2 contained one egg each, and one contained 14 eggs. More recently the writer in the course of one afternoon gathered more than 200 beetles, on flowers of *Leucaena glauca,* of which the one containing the largest number of eggs had only eight.

Observations made in Hawaii, where empty or nearly empty females are often caught in copulo on the flower heads of *Leucaena glauca,* agree with those of E. W. Friend in Connecticut, that more than one mating may take place; but whether any but the first is essential to the oviposition and fertilization of all the eggs has not been determined. However, if a second mating is necessary, the fact that it often does occur explains how females with only a residue of their original egg content might be entirely accountable for the spread of the pest, a supposition which agrees well with the obviously slow rate at which this spread has taken place.

As a whole, the manner and amount of oviposition in the laboratory lay fairly constantly within limits not far distant from the mode. Occasionally, nevertheless, these were widely overlapped. Table I shows the records of 16 females reared in the laboratory, and for comparison Table II shows those of ten females collected soon after emergence in the field. Eggs are laid by day and by night, sometimes singly, but as a rule in batches of from 2 to 12 with intervals usually of a day or two, and often longer, between successive batches. The average lies between 5 and 7 eggs per batch; the recorded maximum being 24. The total number of eggs produced by one female, including a small per cent which, as appears later, is sometimes not laid, averages 30 or 40. Occasionally this number mounts to 50 or 70, and in a single instance recorded in our files by O. H. Swezey, reached a surprising maximum of 103 eggs, including those retained in the ovaries after death. Considerable difference seems to exist between insectary-reared and field material in this respect. As a comparison of Tables I and II shows, the average for 16 reared females was 30 eggs, or 11 eggs less than the average obtained from 8 females collected in the field. This difference becomes more significant considering the uncertainty that females collected in the field had not already laid some of their eggs.

Neither males nor females are ready to undertake their natural functions immediately upon emergence from the pupal stage. It takes about a day for the chitinous integuments to harden, and a somewhat longer time for the internal physiological

adaptations necessary before mating takes place. The interval of time between emergence from the pupa and the first copulation is very likely to vary widely. In at least one case a female copulated and laid her first batch of eggs within 24 hours of emergence from the pupa. In most cases 3 or 4 days pass before mating will take place even between a male and female placed in a small container and jostled together. Such jostling of fresh males with each female as soon as her integuments hardened sufficiently after emergence was the procedure followed in every one of the 16 cases given in Table I; and the average length of this interval of development for 12 laboratory-reared females was 4.5 days, as shown in the last column of the table.

TABLE I

Number	Date of emergence	Date of death	Days alive	Dates and number of eggs laid in each batch (Number of eggs given in parenthesis)	Total No. of egg hatches	Total of eggs laid	Average No. of eggs per batch	Eggs contained in body after death	Potential total of eggs	Date of first copulation	No. of days from first cop. to oviposition	No. of days from emergence from pupa to oviposition	No. of days from emergence to first copulation
1	1/14	1/30	16	1/19(9) 1/21(7) 1/22(?) 1/23(?) 1/26(11) 1/28(4) 1/29(1)	7	40	6—	0	40	?	?	5	?
2	1/29	2/17	20	2/9(5) 2/11(1) 2/13(1) 2/14(5) 2/15(5)	5	17	3+	6	23	2/4	5	11	6
3	2/17	3/4	15	2/18(4) 2/22(3) 2/26(2) 2/27(2) 2/28(3) 3/1(5) 3/2(6) 3/3(1)	8	26	3+	0	26	?	?	1	?
4	2/17	3/4	15	2/21(11) 2/22(5) 2/23(3) 2/24(6) 2/25(1) 2/26(2) 2/27(3) 2/28(1)	8	32	4	2	34	2/20	1	4	3
5	3/1	3/16	15	3/15(6)	1	6	6	27	33	3/4	11	14	3
6	3/10	3/21	11	3/16(7) 3/17(12) 3/18(1) 3/19(8) 3/20(11)	5	39	8—	?	?	?	?	6	?
7	4/29	5/16	17	5/7(16) 5/9(3) 5/12(7) 5/13(5) 5/14(7)	5	38	8—	0	38	5/4	3	9	6
8	7/25	8/11	17	7/30(7) 7/31(10) 8/1(6) 8/2(7) 8/3(3) 8/4(1) 8/5(1)	7	35	5	0	35	7/26	4	5	1
9	8/23	9/6	14	8/29(24) 8/30(8) 8/31(5) 9/1(1) 9/2(5) 9/3(1) 9/5(6)	7	50	7+	0	50	8/28	1	6	5
10	8/25	9/5	11	8/31(2) 9/1(2) 9/2(5) 9/3(1)	4	10	2+	6	16	8/29	2	6	4
11	9/14	10/3	20	9/19(11) 9/22(5) 9/23(4) 9/24(3) 9/25(2) 9/26(2) 9/27(2) 9/29(4)	8	31	4—	?	?	?	?	5	?
12	10/2	10/16	14	10/9(7) 10/10(1)	2	8	4	10	18	10/8	1	7	6
13	10/5	10/18	13	10/10(4) 10/11(9) 10/12(3) 10/13(2) 10/14(3) 10/16(4) 10/17(3)	7	28	4	?	?	10/7	3	5	2
14	11/8	11/25	17	11/16(7) 11/18(1) 11/19(2) 11/21(1) 11/22(2) 11/23(5) 11/24(10)	7	28	4	2	30	11/14	2	8	6
15	11/6	11/22	16	11/15(2) 11/16(12) 11/18(4) 11/19(3) 11/20(6) 11/21(4) 11/22(3)	7	34	5—	3	37	11/14	1	9	8
16	11/10	11/20	10	11/16(5) 11/17(9) 11/18(2)	3	16	5+	0	16	11/14	2	6	4
				TOTALS	91	438			395				72
				AVERAGES	5.6	29+			30+				4.5

TABLE II

Number	Date found	Date of death	Days alive	Dates and number of eggs laid in each batch. (Number of eggs given in parenthesis)	Total number of batches	Total number of eggs laid	Average number of eggs per batch	Eggs contained in body after death	Potential total of eggs
1	2/21	3/10	18	3/1(6) 3/2(9) 3/3(4) 3/4(2) 3/5(1) 3/6(6) 3/8(2) 3/9(7)	8	37	5—	1	38
2	2/25	3/15	18	3/4(2) 3/5(2) 3/6(2) 3/7(3) 3/8(3) 3/10(1) 3/11(3) 3/12(7) 3/13(5) 3/15(2)	10	30	3	26	56
3	3/21	4/6	17	3/26(4) 3/30(8) 4/1(3) 4/2(3) 4/3(8) 4/4(9)	6	35	6—	?	?
4	3/21	4/6	17	3/25(16) 3/26(8) 3/27(2) 3/28(3) 3/29(2) 3/31(2) 4/1(3) 4/2(8) 4/3(1)	9	45	5	0	45
5	9/24	10/3	10	9/26(18) 9/27(14) 9/28(3) 9/29(2) 9/30(6)	5	43	9—	0	43
6	9/15	9/26	11	9/16(1) 9/17(7) 9/18(1) 9/19(5) 9/20(11) 9/21(2)	6	27	4+	?	?
7	9/24	10/11	18	9/26(14) 9/27(15) 9/28(1) 9/29(5) 9/30(10) 10/1(5) 10/2(6) 10/3(5) 10/4(4) 10/5(3)	10	68	7—	0	68
8	9/25	10/4	10	9/26(5) 9/27(6) 9/28(3) 10/1(1) 10/2(13)	5	28	6—	0	28
9	11/25	12/11	16	12/8,9,10,11,12(16) 12/11(3)	6	19	3+	14	33
10	12/24	1/8	15	12/4(7) 12/28(6) 12/31(2) 1/3(4) 1/6(1)	5	20	4	0	20
				TOTALS	70	352			331
				AVERAGES	7	35+			41+

The time between copulation and oviposition is shorter and less likely to vary than that between emergence and copulation. As a rule it is one or two days, though sometimes extending to 4 or 5, and in one instance reaching 13 days. After the first oviposition, egg batches continue to be laid from day to day for about 7 days. As the fifth column of Table I shows, one day can be said to be almost invariably the time elapsing between batches, although it sometimes reaches 2, 3, or 4 days. Only in one instance (Table II, horizontal column No. 10), and this in the case of a field-collected female, did this interval extend beyond the usual maximum of 4 to 14 days.

By the time oviposition ceases, usually all of the fully formed eggs within a female are laid, but it often happens that dead females contain 2 or 3 eggs, some a greater number, and this justifies the question of whether a second period of oviposition, possibly stimulated by a second mating, might not be an occasional, if not usual occurrence under field conditions. Positive evidence in this direction is the fact perhaps, that sometimes in the laboratory, and probably also in the field, females live several days after they cease to lay eggs. Van Zwaluwenburg, for instance, found that out of 77 females 34 died on the same date of oviposition but that 43 lived from one to ten days more, an average of 2.7 days after the last oviposition (unpublished records).

Movements and Distribution of Grubs:

No periodic mass migration of grubs, such as are induced by the more distinct weather variations in Connecticut, can be detected here. Observations in the field and the laboratory, using large soil containers and approximating field conditions as nearly as possible, indicate that in Hawaii the migrations of Anomala larvae are neither rapid nor extensive, and that, other conditions being satisfactory, the presence or absence of food are the main factors in determining their extent and direction.

If a field harbors grubs at all in quantity, its soil is invariably of the right temperature and sufficiently rich in organic matter to provide what seems to be an entirely satisfactory medium for the development of the entire first instar of Anomala. In this stage, therefore, grubs move but little and what has been said about the distribution of the eggs applies equally well to the distribution of the first instar larvae. However, it is only when the surrounding soil is particularly suitable as to moisture and food conditions, particularly when mud press has been applied, that grubs remain feeding and thriving in the same place for the duration of the complete larval life. More usually they evidently migrate until they come into contact with partly dry and rotted bits of cane, or with the living plant itself, under proper moisture conditions. Although this search for the right environment need seldom carry a grub far, it is generally sufficient to segregrate the second and third instar grubs from the eggs and first instars. As a rule, therefore, eggs and first instars are found together, nearer the surface and in greater concentration than second and third instars which are more evenly distributed throughout the soil.

Not very different from the above is the history of the grubs in those cases where a large batch hatches in accumulations of mud press or under a mat of trash, as has already been explained. The grubs may remain close to the surface for the

full length of the larval stage, if moisture conditions remain satisfactory, but usually even thick trash mats and large accumulations of mud press undergo a rather rapid process of thinning and drying out which in 2 or 3 weeks forces the grubs to seek a lower soil level. A varying proportion of the grubs then dies, perhaps often the greater proportion; but those that remain dig deeper into the soil and continue their life-cycle therein.

Pupae are very rarely found in the loose soil near the surface of the ground, where grubs are sometimes plentiful. They are more likely to be at somewhat lower levels, where the packed condition of the soil facilitates the formation of pupal cells; but this need not be more than a few inches deep, and, as a whole, it may be said that the distribution of pupae on a vertical, as well of course as on a horizontal plane, is the same as that of grubs of the second and third instars.

The horizontal distribution of grub population is invariably irregular. Even in the most heavily infested fields, grubs are usually found concentrated into variously sized "patches" of greater density than the areas separating them; and these patches may range widely as to size, shape, and density of the grub population. Some of these "patches" may consist of only one or two isolated stools very heavily infested; others may be larger areas, sometimes gradually merging into each other, or just as often, sharply delimited.

The causes of this peculiar distribution are probably not always the same. Certain well established peculiarities of the behavior of Anomala seem to account quite well for most cases; the nature of these probable factors permits the supposition that sometimes they act singly and sometimes in different combinations with one another. On the other hand, recent work by H. A. Wadsworth of the University of Hawaii and R. H. Van Zwaluwenburg of our staff, indicates that differences in the physical characteristics of the soil, as these affect its moisture-holding capacities, and to variations of which the Anomala egg and early stages are exceedingly sensitive, might provide sufficient explanation of the phenomenon even without taking into consideration other more obvious factors.

The tendency of Anomala females to deposit most of their eggs near the point of emergence from the soil is probably the most important of these other factors. Another one would be the exclusive dependence of Anomala larvae on some product of the cane plant for food in cases where the soil itself, for one reason or another, is not a satisfactory growth medium.

Observations in the laboratory, using large soil containers and approximating field conditions as nearly as practicable, indicate that the migrations of Anomala are neither rapid nor extensive and that other conditions being satisfactory, the presence or absence of food is the main factor in determining their extent and direction.

Though very simple, it may be worth while to detail here the experiments from which these observations were made.

For the first experiment two boxes, numbered one and two for the sake of convenience, with inside dimensions of 14 by 16 by 24 inches, were each filled with two different types of soil, in such a manner that the right half of each box contained soil with a minimum of visible organic contents from a field where Anomala were not present, while the left half contained soil very rich in trash and taken from a

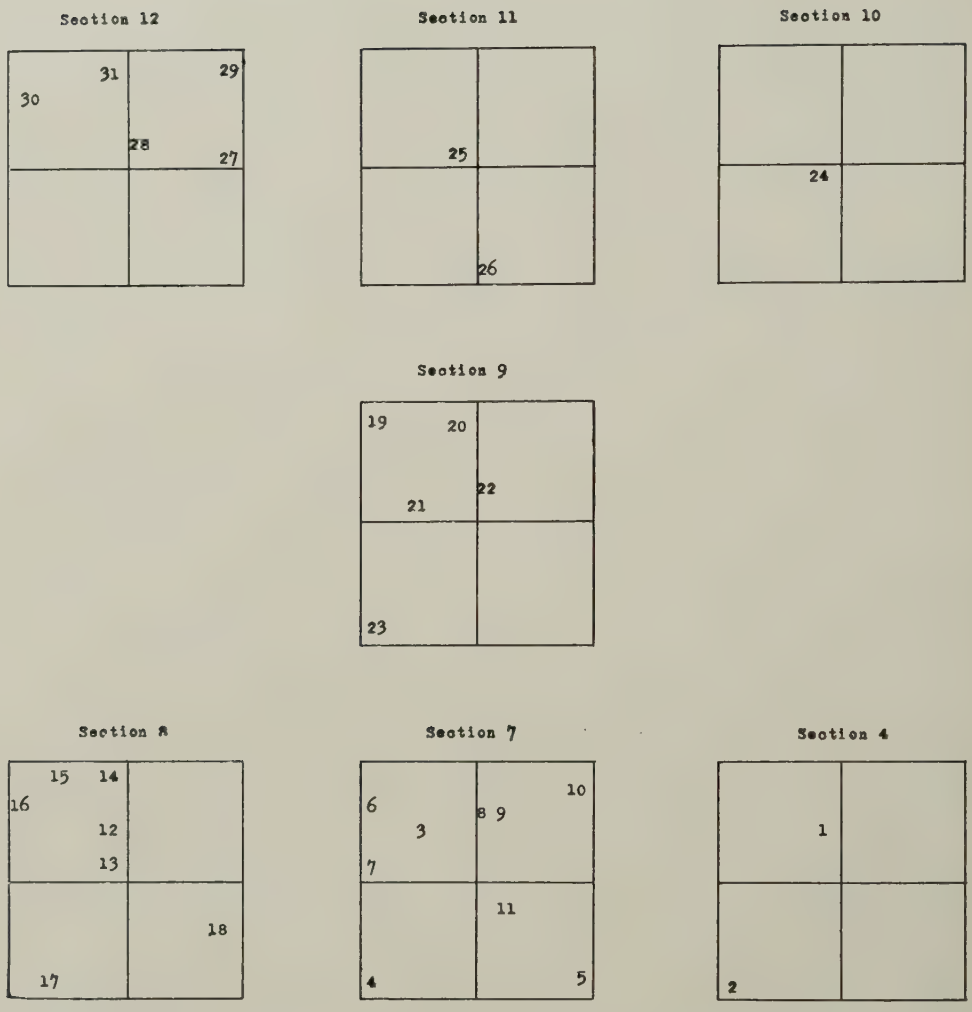


Fig. 1. FIRST MIGRATION EXPERIMENT, BOX NO. 1 (Vertical Section). Sections 12 to 7 comprised the trashy end of the box. Section 4 held the only 2 grubs which had moved beyond the trashy end. Intermediate sections are not shown.

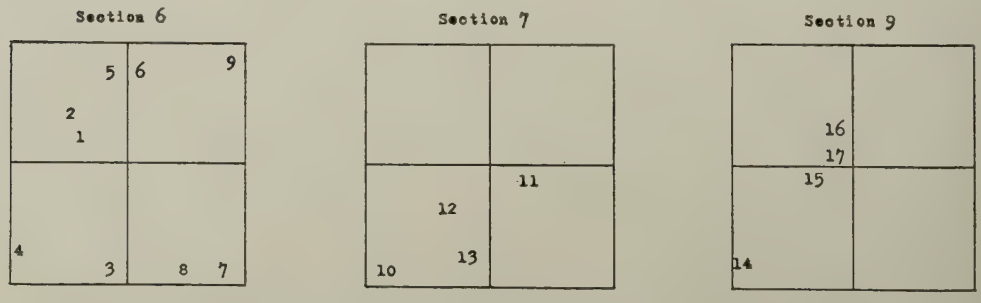


Fig. 2. FIRST MIGRATION EXPERIMENT, BOX NO. 2 (Vertical Section). All the sections shown here were in the trashy soil end of the box. Both trashy and non-trashy sections which showed no grubs are omitted.

thickly infested field. After watering daily and allowing the soil to settle for a week, it was allowed to dry down to an estimated field condition. Thirty-five freshly dug and quite healthy third instar grubs were then placed in each box; those in box number one were placed in a shallow groove along the surface of the trashy soil, while those in box number two were similarly placed in the trashless soil. Both boxes were then allowed to remain undisturbed for 15 days, after which one end and both sides of each box were removed, the boxes being so made that this could be done easily, and the remaining blocks of soil were carefully scraped off in thin cross-sections, record being made of the position of each grub.

The results obtained from this experiment are given in the following figures. Each square represents a two-inch section of soil, and each number corresponds to a grub and is placed in the proper relative position. There were 12 two-inch sections in each box, numbered consecutively from the poor to the rich soil end, but here are shown only those sections in which grubs were found; and record is made only of grubs, or of freshly emerged beetles which could be judged with reasonable certainty not to have moved from the place where they had pupated.

It will be seen that in box No. 1 (Fig. 1) where the larvae were placed in the rich soil, 31 out of 35 survived and all but two remained in trashy soil, the majority remaining in the upper half and evidently having moved but little during the time they remained in the box.

Fig. 2 shows that in the box where the grubs were originally placed on the poor soil, only 17 had survived and all had migrated to the trash. It is curious to note that 9 larvae, more than half of the total surviving, are found in section No. 6, indicating that for most grubs migration is over when food is found. This fact is also indicated by a comparison of the vertical distribution of the larvae in both boxes, which shows that in box No. 1, 21 out of the 31 surviving grubs remained in the upper half of the rich soil, while in box No. 2, 7 larvae were found in the upper and 10 in the lower half, showing a more even distribution, and therefore indicating more movement in poor than in trashy soil.

A second experiment on the migration of Anomala larvae corroborated the results of the one just detailed and gave some additional data on the distance that grubs may cover in their search for food. Using the same boxes and the same two types of soil, box No. 1 (Fig. 3) was filled entirely with poor soil from a non-infested field, except for a portion in the upper right hand corner, 8 inches deep, 8 inches long, and as wide as the box, which contained the soil mixed with trash. Box No. 2 (Fig. 4) was similarly filled, but the trashy soil was placed in the lower right hand corner. After a week of daily watering and another week of settling and drying to an approximate field condition, 35 grubs were introduced into each box, being placed in each case in a shallow groove in the corner diagonally opposite to the trashy soil. In this manner the grubs of box No. 1 had to move approximately 18 inches along an upward diagonal to reach the nearest trash, and those in box No. 2 had the same distance to move along a downward diagonal.

Thirty-two days after introducing the grubs, the sides and one end of each box were removed, and the soil carefully examined in the manner of the first experiment. The following diagrams, in which the cross-hatching indicates the presence of trash, show the results obtained.

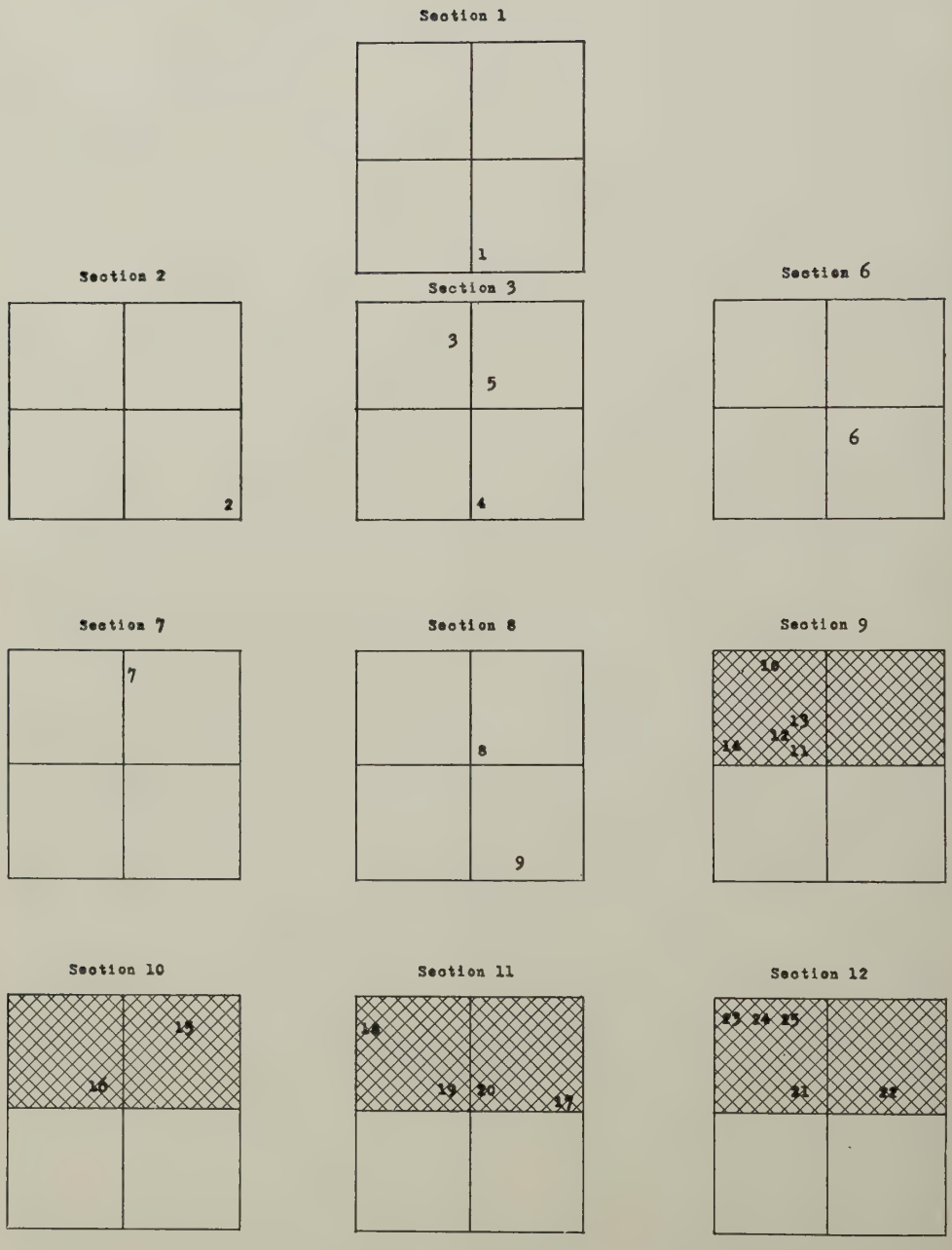


Fig. 3. SECOND MIGRATION EXPERIMENT, BOX NO. 1.

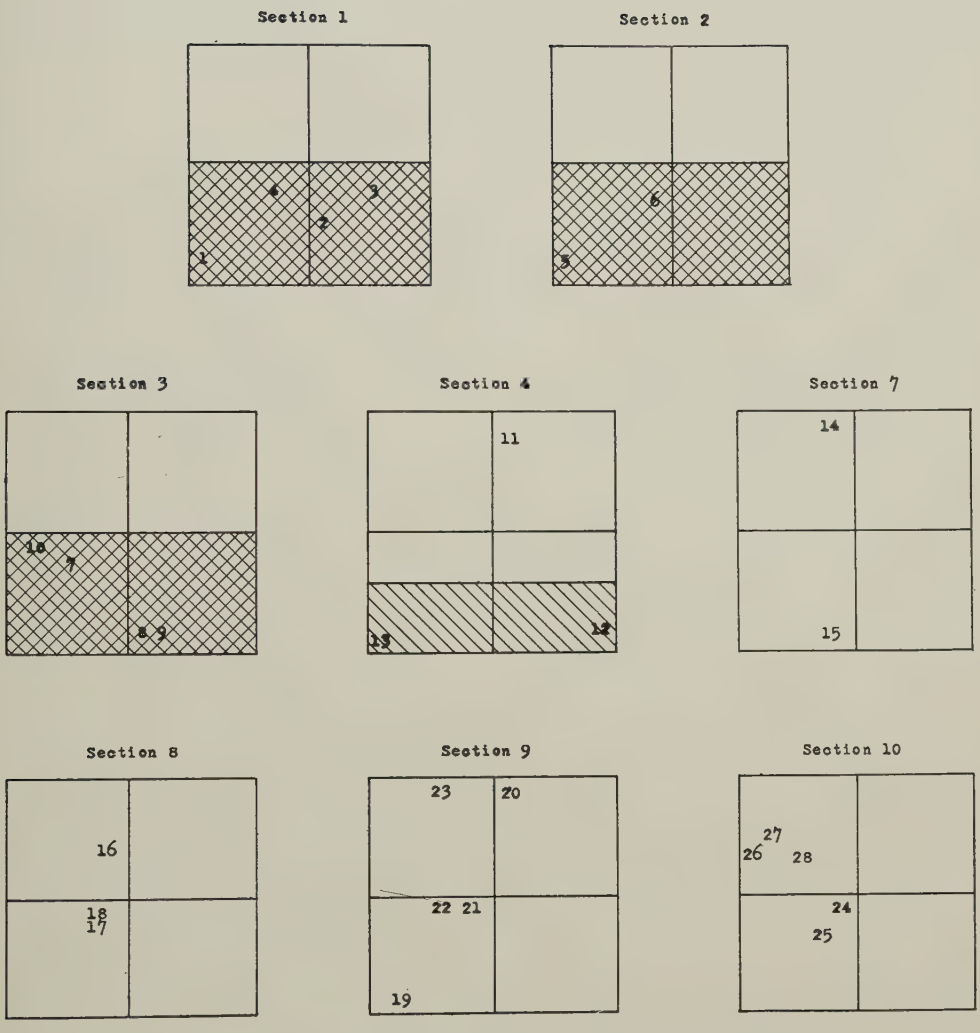


Fig. 4. SECOND MIGRATION EXPERIMENT, BOX NO. 2.

These results are not significantly different from those of the first experiment. Sixteen out of 25 grubs were found in the trashy soil in box No. 1, and 12 out of 28 in box No. 2. There is seemingly no tendency to prefer either a downward or upward course, and, as before, with other conditions satisfactory, food seems to be the main factor in determining the distribution of the larvae, although their migration is evidently very slow and their eventual contact with food seems to be a matter of chance rather than the result of any definitely oriented movement.

Food Habits of the Grub:

Friend states that in Connecticut young larvae feed on both grass roots and dead organic matter. As in the cane fields of the Oahu Sugar Company, Ltd., grass is usually quite scarce, it is probable that the first instar of Anomala lives and thrives almost entirely on the bacterial or organic content of soil which is continuously being passed through the alimentary canal. The second and third instars also ingest quantities of soil in the same manner, and may in many cases attain full development without consuming any other food. This has happened with laboratory-reared specimens. As a rule, however, the food of second and third instars in the field consists largely of different parts of the sugar cane plant, either in the living condition or in various stages of decomposition.

The common notion that the actual roots of the cane plant constitute the main article of fare is apparently erroneous. As a matter of fact all observations, both in the field and in the laboratory, indicate that grubs exercise but little choice in the matter of food, eating indiscriminately the nearest available cane plant material and moving on aimlessly in further search when this is consumed. This fact explains why an evidently heavy infestation of grubs is not accompanied always by a correspondingly great amount of damage to the cane. Other factors may account for this in some cases of course, but it is quite probable that often in fields where buried cane trash is abundant a large portion of the grubs to be found in the field are harmless, as far as the living cane is concerned.

The softer portions of the available food material seem to be more readily attacked, as might be expected. The pith of dry or semi-dry stalks is thus very often eaten, the grub making its way into the cane from one end, while the cortex remains unharmed. In the same way, eyes and young shoots are often partly or wholly devoured while the rhizome remains intact; but the opposite condition is also not rare, stools sometimes being found in which only the old, soft portions of the rhizome have been damaged, while the harder portion, supporting the eyes and buds, remains intact. In the case of seed pieces a very definite concentration of the area of damage has sometimes been observed, the eyes and the zone of adventitious roots being completely girdled out of otherwise practically unharmed cane.

Individual grubs in the laboratory varied considerably in their feeding habits. All of them would eat regularly of soil or trash during the first and second instar, but it was not unusual to find some of them that almost or possibly quite completely stopped eating sometime after entering the third instar. It was very evident that those that ate the most were the ones which could be expected to pupate relatively early; while a large proportion of the others would simply live on inactively and

indefinitely until attacked by some fungus or bacteria. One of these grubs survived for 318 days without consuming during its whole life a volume of food much larger than its own body at the point of greatest development.

It is interesting to note that these differences of behavior often occurred in the laboratory between grubs from the same batch of eggs, reared together in the same container. The cause or causes of these differences of behavior have not been ascertained.

Broods:

Entomologists who worked with Anomala before the introduction of Scolia believed that the pest produced two broods, possibly three, a year; but they were uncertain whether or not that was the case, and it seems improbable to us in the light of data gathered under less pressing demands for measures of immediate relief.

As far as it has been possible to determine the point, a number of generations are produced annually in the field. Overlapping is very great during the warm middle months, and, at least seemingly, lessens quite perceptibly after September. If overlapping actually diminishes it may be attributed to a general lengthening of the third instars of the last summer generation of grubs, most of which seem to remain in the soil longer than preceding generations, giving rise to a slowly trickling stream of emergence and oviposition which does not regain full vigor until the return of favorable conditions. However, it may quite well be that no such diminution of overlapping actually takes place, and that it only appears to occur as a result of the comparatively greater ease with which third instars are found because of their larger size and more general distribution through the soil, when these as well as all other stages of Anomala become relatively scarce in the fields. This condition, which invariably develops during the last months of the year, is due, perhaps, to more than a single factor, but is certainly in a large measure due to the efficient work of the introduced parasite, *Scolia manilae*.

Determination of the actual number of generations produced in the field is hardly possible because of the large degree of overlapping which is found whenever Anomala is abundant enough to make any sort of grub counts practicable. Judging from the results obtained in laboratory breeding work, under conditions probably far from ideal, as many as four generations might develop each year. This would allow around 90 days for the development of each generation; and the assumption that such a figure is nearly correct for at least the warm-weather generations offers an explanation of the very sudden rise—within 2 or 3 months—of Anomala population which is observed at times in fields where grubs left over the winter were so scarce as to be very difficult to find. Nevertheless, it is not to be doubted that in respect to larval life-lengths Anomala reflects in the field the almost limitless variety of environment which any field can provide. The wide overlapping of generations can hardly be due to any other factor.

Taking all that we know into consideration, it is almost certain that there is not even one brood of definite seasonal emergence. Abundance of beetles at certain times, which might be taken as an index of the time of emergence, is probably not due to Anomala's biologic habit, but to the seasonal concurrence of a number of

ecologic factors which cause very strikingly contrasted periods of alternate abundance and scarcity of the pest. If it did depend only on a biologic habit of the insect we could expect to find it occurring simultaneously over the whole infested area regardless of the age of the crop cover; but actually the time of greatest abundance varies from field to field, and, as a rule, coincides with cane not more than a few months old. Apart from that, in some fields it continues throughout spring and into late summer; much longer than we can expect a brood to last, regardless of overlapping, in case of an insect whose adult stage is only from 2 to 4 weeks.

It is easy to see why the point of maximum accumulation should be generally reached, as it is, late in spring. On the other hand, occasional wide divergence of individual fields from the general rule, observed more than once, does not become unexplainable, as it would if beetle abundance were due to seasonal brood emergence.

The Behavior of Adults in the Field:

When beetles are abundant above ground males are almost invariably far more numerous than females and can be found resting on weeds, trash, or cane leaves at any hour of the day. Although their antennae are usually outstretched and in slow movement, as if in constant expectation or actual reception of sensory stimuli of some sort, they are generally rather inactive and only a few can be seen commonly on the wing at one time. There are, nevertheless, periods of distinctly increased activity when all or most of the beetles rise in flight simultaneously. At such times they seem to rise in response to a stimulus which is, or coincides with, a sudden drop of the atmospheric temperature, either as when the sun is obscured by passing clouds in which case activity may last only a few minutes, or as when the sun is hidden in consequence of its downward path below the horizon, then activity suddenly begins and lasts with varying but gradually diminishing intensity until darkness sets in.

The object of the beetles' flight during crepuscular periods of activity seems to be to migrate from the exposed stations on which they can be found during the day to more protected locations under trash and surface soil, where most of them spend the night; and it is probably in search of the same protection that they fly when rain or cold is presaged by passing clouds. This object is less evident, however, during the day than in the evening, and the fact that often there is no apparent diminution of the number of beetles on exposed places during heavy showers points to the possible existence of a different cause for diurnal as compared to crepuscular activity.

The movement from soil and trash to the more exposed locations is not accomplished in concert. It gives rise, rather, to a trickling stream of individual flights which begins with the first warming of the air in the morning and continues through the day; its volume seems to vary from hour to hour and day to day, and is apparently greater in warm, sunny weather than when it is cold or rainy.

The dull thud, with which Anomala males often collide against leaves of cane plants or against the backs of their human visitors, suggests a greater potential ability for prolonged flight than the writer has ever seen actually exercised. The males never fly directly to a point, and seldom, if ever, rise higher than a man's head. Their flight is always of short duration, more or less spiral, and always seemingly erratic, succeeding more often than not in bringing the insect back to within a few

feet of its point of departure. There have been one or two occasions, however, when the flights of several males were observed by the writer to be drawn to a common point of convergence by the presence of a female, and in these cases, although each individual wasted much effort in useless spiraling, most of them finally landed within a foot or two of the female.

Females, which the writer has observed on the wing, behaved in a manner apparently no different from that of the more numerous males, providing no foundation for the belief that females may arise in mass to migrate directly from one field to another. Quite commonly during the earlier years of Anomala's presence, at the present time less frequently, unusual numbers of females have been found congregated on flowers, particularly on those of *Leucaena glauca,* but this has never been known to happen unless flowers were growing within or immediately adjacent to infested fields. The movement to these flowers has been observed by the writer to take place not by migration in mass but through the flight of isolated individuals. The gradual accumulation of females on flowers during the day, and their more nearly simultaneous flight back to the soil at dusk, are, as a matter of fact, activities exactly parallel in appearance to those of the males in moving to and from the cane leaves on which they are usually found during the day.

The fact that females are not at present conspicuous as seems to have been the case in former years, is probably due to the more occasional concurrence of attractive flowers and females in closely adjacent locations. It would seem that it is a regular and general habit of females—after laying most of their eggs as discussed earlier—to frequent flowers; but the distance which they can traverse to do so, or the distance from which they are able to perceive the flower, is rather limited. How limited this flight is can perhaps be judged from the fact that the writer has never found females farther than 30 feet from a focus of grub infestation.

It is a curious fact that in infested fields beetles are as unevenly distributed on the surface as grubs are underground. Large portions of a field will show only a few beetles, whereas certain scattered areas, during active periods, will be alive with their buzzing, as if beetles tended to retain the original concentration of their larvae rather than to disperse in every direction, as one would expect them to. In some cases this concentration takes place in response to the attraction of females; it is not unusual to find large numbers of males crawling over and around mating couples. In most cases it is perhaps due merely to a purely gregarious instinct, as it is not uncommon to find large clusters of males spending the night together in propitious locations under loose soil or trash, unaccompanied by females.

In frequenting flowers, in the case of *Leucaena glauca,* females do so to feed exclusively upon the pollen and pollen bearing elements of the flower. The petals of other flowers also seem to be relished, as in the case of hibiscus, petals of some varieties of which serve very well as a laboratory diet for the beetles. Whatever the variety of flower, it is probable that the scent rather than the sight of the flower guides Anomala to it. That being the case, the beetles' habit of frequenting flowers suggested experiments conducted in the field on the possibility of attracting them to baited traps; but the results, although not entirely negative, proved discouraging. Using traps of a pattern devised and previously employed by entomologists of the

U. S. Department of Agriculture in connection with similar research on the Japanese Beetle, our trials were made with six different volatile oils, applied in each case at the rate of one drop of oil to each portion of the following formula, secured from the Moorestown Experiment Station: 50 grams of bran, 26 cc. of cane molasses, 4 cc. of glycerine, 9 cc. of water, and 0.1 gram of benzoate of soda. Six traps, each with a different oil, were used simultaneously, all being placed within 100 feet of one another in a field chosen for the exceptional abundance of beetles above ground. Changing the site each time, the experiment was repeated two times within as many months in 1932—having been conducted once in 1931. As the results were entirely negative in all but one case, only that instance is recorded in the following table.

TABLE III

THE RELATIVE ATTRACTIVENESS OF SIX VOLATILE OILS FOR ANOMALA ADULTS

Traps Set Out April 9, 1932.

	Geranol	Anisic Aldehyde	Terpineol	Citronellol	Amyl Acetate	Ethyl Benzoate
April 14....	Anomala 1	Anomala 1	Anomala 1	Anomala 1		
	Anomala 0	Anomala 0	Anomala 0	Anomala 0		
	Scolia 6	Scolia 8		Scolia 2		
				Adoretus 1		
April 17....	Anomala 2	Scolia 3				
	Anomala 0					
	Scolia 5					
April 21....	Anomala 1	Scolia 1		Anomala 1		
	Anomala 0					
	Scolia 2					

As only female Anomalas were captured, and as these are almost at all times scarcer than males in the field and certainly were so in this particular instance, the results of this experiment definitely show a certain degree of attraction of at least four of these oils for the female beetle; the attractiveness of Geranol was somewhat greater, perhaps, and lasted somewhat longer than that of the others. However, the fact that all of the trapped females turned out to be entirely devoid of eggs, together with the fact that the oils seemed to have as much or more attraction for Scolia females than for Anomala, showed the uselessness of further experimentation with this method of control.

Entirely negative results were obtained with similar experiments when the same traps were baited with cane molasses, honey, or a mixture of both.

Life History in the Laboratory

The results of life history work done in the laboratory are given herewith. The scarcity of Anomala beetles and grubs in the field during a large part of the time the work was carried on, added to the natural difficulties of determining the life history of grubs under the best of laboratory or field conditions, explains their meagerness.

Lacking space and facilities for the purpose, no effort was made to keep constant temperature, or in any way to control the conditions under which Anomala

material was reared. It was merely kept under an open lean-to where temperature changes roughly corresponded to those of the open air. The records, therefore, can hardly be more than an indication of field possibilities; but, as such, they are in satisfactorily close agreement with results obtained by Mr. Van Zwaluwenburg in a more careful and detailed continuation of life history studies now being carried on.

Several methods of breeding Anomala under observation were tried. At first an effort to approximate field conditions was made by keeping grubs in boxes and other large soil containers; but it was soon found that the use of large containers, some of which were buried in the ground, only increased the necessary labor, without reducing the mortality of young grubs, which was the main difficulty faced in securing the desired data. The method finally adopted was the use of tin pill boxes 2½ inches in diameter and ¾ inch in height, not quite filled with soil and pieces of cane rhizome, and kept on a shelf at ordinary shade temperature. Unless extraordinarily large, each batch of Anomala eggs, averaging from one to ten, was hatched in a single pill box wherein the grubs were also allowed to remain together. Naturally, in this way each batch would soon be thinned out to one or two grubs per box, but this was found to be the eventual fate of every batch of grubs kept in the laboratory, regardless of the manner of keeping them. After only one or two grubs out of each batch were left they became, of course, much easier to observe and to keep supplied with food and moisture in small containers than it would have been in large ones.

The most striking fact brought out by this work was the great range in the duration of the various instars of the grub stage of Anomala. This becomes even more striking when it is considered that in several cases widely separated figures in the tables here given represent instars of grubs from the same batch of eggs, reared together within the narrow limits of ecological variation determined by the size of a pill box. One is led to suspect that the range of dispersion must be even greater under the uneven environmental conditions of a cane field.

It would have been interesting to ascertain the degree of correlation that exists between the lengths of the various instars of the same grub, but due to the heavy mortality in all stages of the reared material very little data could be secured bearing on this point. As it was, this correlation seemed entirely negative, as Table IV will show. Therein are given the only 3 complete beetle histories obtained.

TABLE IV

Beetle	Sex	Length of 1st instar	Length of 2nd instar	Length of 3rd instar	Pupal Stage
1	?	44 days	20 days	90 days	? days
2	?	15 days	24 days	105 days	? days
3	Female	29 days	26 days	68 days	7 days

Table V presents in condensed form the lengths of 67 first, 48 second, and 11 third instars.

TABLE V

	Minimum length	Maximum length	Average	Probable error
67 1st inst.....	11 days	54 days	24.2 days	.58
48 2nd inst.....	10 days	66 days	28.7 days	1.2
11 3rd inst.....	47 days	176 days	105.2 days	Very large

Table VI gives the total lengths of 37 larval stages, from hatching of the egg to pupation of the full-grown grub. Both this table and the preceding one, Table V, show wide dispersion, but as in Table VI, 20, or more than half of the 37 items, fall within the interval of 140 to 190 days, while the rest spread over a much larger range, the average figure of 172.3 days is probably fairly representative. It is to be noticed, however, that neither of these tables shows the entire possible range of the larval stage. It can be considered longer than here indicated because these tables are computed only from grubs which actually pupated; whereas, as already noted, a few larvae kept under observation in the laboratory showed an unusual protraction of the third instar that might eventually have terminated in the grub's pupation, but which for one or another extraneous reason was not brought to an end in that manner. One of these grubs, the longest lived, survived for 318 days—others approximately that long.

Due to the arrangement of the figures in progressive order as shown in Table VI, a glance shows that there is no correlation between length of larval life and time of egg hatching, but it must be noticed that all of these grubs were hatched during the third, fourth, fifth and sixth months of the year, between which months changes in temperature are very slight. Had it been possible to begin rearing a certain number of grubs each month of the year under conditions so controlled as to reflect the seasonal weather variations of the field, it is quite probable that a correlation between length of larval life and time of oviposition such as evidently occurs in the usual field environment of Anomala, would have appeared.

In Tables VII and VIII the items are too few to permit the use of the results as basis for any definite conclusion, being in close agreement with all other data thus far obtained by our department; they are, however, probably correctly indicative. As can be seen, the range in the duration of the pupal stage is rather small in the case of both sexes. On the other hand, this range is rather wide in the case of both male and female adults. As the results agree with later observations made by Mr. Van Zwaluwenburg, the slightly longer averages of the males over the females, for both pupal and adult stages, seem to be significant; and it is curious to note that this agreement exists in spite of the fact that his beetles were continuously fed on hibiscus flowers, of which they are very fond, whereas those of the writer were not fed at all.

TABLE VI

TOTAL LENGTH OF LARVAL LIFE OF ANOMALA FROM HATCHING OF THE EGG TO PUPATION OF GRUB

Item No.	Date Egg Hatched	Date of Pupation	Total days of Larval Life
1	4.20	7.10	82
2	3.27	7.19	115
3	6.17	10.8	114
4	3.26	7.19	116
5	3.16	7.13	120
6	3.17	7.16	122
7	12.31	4.15	134
8	4.20	9.14	148
9	4.17	9.14	151
10	5.29	10.28	153
11	10.41	3.7	155
12	4.11	9.5	158
13	4.11	9.5	158
14	5.22	10.27	159
15	4.24	9.29	159
16	5.24	10.30	160
17	3.22	8.29	161
18	4.22	9.30	162
19	5.24	11.1	162
20	3.18	8.26	162
21	3.18	8.28	164
22	3.20	9.5	170
23	4.12	10.4	176
24	9.13	3.7	177
25	3.20	9.15	179
26	3.30	9.28	183
27	4.20	10.20	184
28	4.20	10.27	191
29	6.25	1.11	201
30	4.20	11.16	211
31	6.20	1.21	216
32	6.81	1.22	229
33	5.27	1.11	230
34	5.28	1.30	248
35	5.22	1.21	245
36	4.20	1.1	257
37	4.21	1.11	266
		TOTAL	6378
		AVERAGE	172.3

TABLE VII

LENGTH OF PUPAL AND ADULT STAGES OF MALE ANOMALA BEETLES

Item No.	Date of Pupation	Date of Emergence	Date of Death	Days as Pupa	Days as Adult
1	August 18	August 26	September 8	8	13
2		December 1	December 27		26
3		April 7	April 19		12
4	May 20	May 31		11	
5	September 30	October 10		10	
6	September 4	September 14		10	
7	August 29	September 7		9	
8	January 26	February 10		15	
9	January 15	January 27	February 15	12	19
10	January 11	January 25	February 15	14	21
11		January 5	January 31		26
12		January 13	February 1		19
13		February 23	March 3		8
14		February 27	March 9		10
15		February 11	February 20		9
16		March 8	April 1		
17		March 13	April 2		
			AVERAGES	11.1	16.3

TABLE VIII

LENGTH OF PUPAL AND ADULT STAGES OF FEMALE ANOMALA BEETLES

Item No.	Date of Pupation	Date of Emergence	Date of Death	Days as Pupa	Days as Adult
1	November 15	November 28	December 7	13	10
2	March 22	April 2		11	
3		May 14	June 1		18
4	May 15	May 22		7	
5	May 15	May 23		8	
6	May 15	May 24		9	
7		May 21	June 1		11
8		May 22	June 15		24
9		April 13	May 14		31
10		July 20	August 1		12
11		March 10	March 21		11
12		February 17	March 4		15
13		January 29	February 17		19
14		March 1	March 16		15
15	April 16	April 29	May 16	13	18
16		July 25	August 11		17
17	August 14	August 23	September 6	9	14
18	August 16	August 25	September 5		11
19		October 2	October 16		14
20		October 1	October 13		12
21		October 5	October 18		13
22		November 8	November 25		17
23		September 14	October 3		19
24		November 6	November 22		16
25		January 14	January 30		16
26		November 10	November 20		10
			AVERAGES	10.0	15.5

TABLE IX

LENGTH OF THE PERIOD OF INCUBATION OF BATCHES OF ANOMALA EGGS LAID IN THE LABORATORY DURING THE VARIOUS MONTHS OF THE YEAR

Month	Number of Batches	Minimum Incubation	Maximum Incubation	Average Incubation	Mean Monthly Temperature
January	7	21 days	23 days	22.1 days	64.5° F.
February	3	18 days	19 days	18.3 days	65.9° F.
March	22	16 days	21 days	19.1 days	62.2° F.
April	17	16 days	22 days	18.1 days	65.2° F.
May	6	14 days	15 days	14.8 days	66.5° F.
June	5	14 days	15 days	14.4 days	67.2° F.
July	..	.....	.....	.....	.....
August	7	14 days	20 days	15.4 days	67.0° F.
September	9	12 days	16 days	16.3 days	66.0° F.
October	15	12 days	18 days	14.5 days	68.0° F.
November	..	.....	.....	.....	.....
December	4	18 days	22 days	21.0 days	64.9° F.

While not correlating perfectly, the monthly averages for the incubation period of Anomala eggs, as given in Table IX, reflect clearly the general tendency of the temperature curve for the year. By arranging the months of the year in two columns, as follows, in which the first column is in the order of the progressive decrease of the mean incubation period, and the second one in the order of the progressive decrease of the mean monthly temperature, this correlation can be seen at a glance.

Length of egg stage decreases in this order:	Mean monthly temperature decreases in this order:
June	October
October	June
May	August
August	May
September	September
April	February
February	April
March	December
December	January
January	March

Correlation is, of course, to be expected between variations in temperature and the length of the period of egg incubation; but a great deal of work now being carried on by Prof. H. A. Wadsworth and Mr. Van Zwaluwenburg under carefully controlled conditions is showing this correlation to be very delicate, thereby throwing light on its probably very great importance in the field.

In Table IX the figures refer to egg batches as a whole, rather than to individual eggs. It was never noticed in this work that individual eggs of the same batch, kept together in the same small container, differed by more than a few hours as to the length of the incubation period, and these small differences are overlooked. As at least two daily observations were made of the material, however, it is probable that the figures are accurate to within 12 hours.

Emergency Conservation Work

Associate Forester's Narrative Report Island of Kauai—For Fifth ECW Period*

This report covers the work of our program of Men Working From Homes from April 1 to September 30, 1935 and the camp program from July 22 to September 30, 1935. Construction of the camp began on May 17, and it was completed on August 16, 1935. Men for the camp were enrolled on July 8, 1935, and after a two weeks' conditioning period, work started on approved field projects on July 22. Men working from homes were paid at the rate of $2.00 per day, 5 days per week, the camp enrollees being paid $30.00 per month plus subsistence, shelter, clothing and medical care.

Men Working From Homes—the maximum enrollment allowed was 54 men and 5 field foremen. Six men were employed in nurseries and 48 men on field projects. The men were divided into five groups in accordance with the various districts on the Island. At the start of the camp program, the group including the foreman working in the district in which the camp is located was transferred to camp. Another foreman was transferred to camp and promoted to Project Superintendent, leaving 45 men and 3 foremen.

The authorized strength of the camp is 100 enrolled men with a Supervisory personnel consisting of a Director, Project Superintendent, Quartermaster and Recreational Officer, Clerk and 5 Foremen.

During the period a total of 9,120 man-days was expended on all projects. Due to the fact that the camp enrollees did not start work on projects until July 22, a number of the contemplated projects remained incomplete at the termination of this period. These will be completed along with the program prepared for the ensuing period commencing October 1, 1935.

Work Projects

The work program for this island includes the following approved projects as listed on ECW Form-7—N. P. & M.:

1. Fences, Construction and Maintenance
2. Field Planting and Maintenance
3. Foot Trails, Construction and Maintenance
4. Horse Trails, Construction and Maintenance
5. Truck Trails, Construction and Maintenance
6. Minor Roads, Maintenance
7. Erosion Control, Planting and Maintenance
8. Dwellings, Improvements
9. Water System
10. Bridges
11. Structures
12. Razing Undesirable Structures
13. Eradication of Plant Pests
14. Seed Collection
15. Nurseries

* We are indebted to E. E. Tillett, Field Supervisor, Emergency Conservation Work for Hawaii, for the privilege of printing this report by Albert W. Duvel.

WORK ACCOMPLISHED

BY L. V. ALEXANDER, PROJECT SUPERINTENDENT

A. Camp Projects

During the Fifth Period from July 8 to September 30, 1935 inclusive, a total of 360 man-days was expended on conditioning period and 3,439 on work projects. The cost of materials used on projects totalled $336.57. Total Supervisory costs were $1,634.50.

During the conditioning period, 360 man-days were expended on various forms of activity and work to get the enrollees in condition. One-tenth of a mile of truck trail was built for the camp. Four thousand eight hundred forty square yards of fine grading and road bank sloping were taken care of. One thousand seventeen trees and plants were brought from the Forest Reserve and placed in and around the camp. One dump was obliterated. One acre of ground was sodded with grass and one acre of ground thoroughly prepared preliminary to planting. About 210 cubic yards of excavating were done and the dirt used to fill in other places. One hundred cubic yards of stone were broken for use around camp. One thousand lineal feet of rock lining were constructed to form walks around the barracks. Twelve yards of sand were hauled for use in the camp. Nine hundred two feet of ditching were constructed within the camp and fifty cords of firewood were cut for the camp wood supply.

Field Projects

1. Fences:

ECW Form-7 No. 131. This project consisted of the repairing and maintenance of 168.4 rods of fence along the Puu Ka Pele Forest Reserve boundary. A total of 44 man-days was expended on this project. Material costs: $4.25. Supervisory costs: $21.60.

2. Field Planting and Maintenance:

ECW Form-7 No. 501. Field planting and maintenance work was carried on in the Puu Ka Pele Forest Reserve. A total of 49 acres was planted. Nine thousand one hundred forty-three trees were planted, spaced at a distance of 15 x 15 feet. Under maintenance, 242 acres were cared for. Fifty-seven thousand two hundred ten trees were hoed free from grass, weeds, and brush, and 5,269 trees were replanted. The three varieties used were Grevillea robusta, Acacia koa, and Eucalyptus rudis, these having been found to be the varieties best suited for the conditions prevailing in this section. Man-days expended for the new planting and maintenance were 269. Material costs: none. Supervisory costs: $121.27.

3. Foot Trails, Construction:

ECW Form-7 No. 206. This project consisted of the construction of seven-tenths of a mile of foot trail along a very steep and rugged section of the Puu Ka Pele Forest Reserve boundary to facilitate fence patrol and tree planting. Forty

man-days were expended on this work. Material costs: none. Supervisory costs: $17.95.

4. Horse Trails, Construction and Maintenance:

ECW Form-7 No. 207. This project consisted of the construction and maintenance of horse trails within the Puu Ka Pele and Na Pali Kona Forest Reserves. Nine miles of horse trails were built with an expenditure of 650 man-days. Material costs: none. Supervisory costs: $270.12.

Seven miles of horse trails were partially completed. Three hundred eighty-two man-days were used on this work. Material costs: none. Supervisory costs: $168.70.

Horse trails, maintenance—29½ miles were placed in serviceable condition. A large number of steep grades were reduced to conform with Park Department regulations. A total of 1,357 man-days was expended on this work. Material costs: none. Supervisory costs: $745.11.

5. Truck Trails, Maintenance:

ECW Form-7 No. 202. This project consisted of truck trail maintenance in the Na Pali Kona Forest Reserve, Kokee. A total of nine-tenths of a mile of truck trail was placed in serviceable condition. One hundred nine man-days were expended on this work. Material costs: none. Supervisory costs: $44.23.

6. Minor Roads, Maintenance:

ECW Form-7 No. 203. This project consisted of the maintenance of 3.2 miles of minor roads within the Na Pali Kona Forest Reserve. This work was especially needed to give access to the various trails and work projects within the region. Two hundred thirty-eight man-days were expended on this project. Material costs: none. Supervisory costs: $112.40.

7. Dwellings, Improvements:

ECW Form-7 No. 110. Maintenance of Ranger Station dwelling at Kanaloluhuhulu. This work consisted of covering the outside walls with heavy building paper and shingles, staining shingles and painting the trimming. A total of sixty man-days was expended on this project. Material costs: $122.80. Supervisory costs: $26.40.

8. Water System:

ECW Form-7 No. 143. This project consisted of a pipe line and water system at the old Na Pali Kona Ranger Station, Kokee. The project was only partly completed at the end of this period. A dam has been constructed on the main Kokee Stream to furnish a water supply. Owing to conditions existing at the dam site, rather more time and material were required than originally estimated. Forty-five man-days were expended on this project. Material costs: $209.52. Supervisory costs: $19.80.

9. Eradication of Plant Pests:

ECW Form-7 No. 1004. This project consisted of the eradication of blackberry in the Kokee Region of the Na Pali Kona Forest Reserve. This plant with others of the family group has spread, covering a large area and forming an impenetrable mass. It has been necessary to keep after the new growth continually and to remove every root that can be found within the vicinity. A total of nine acres has been cleared off, with an expenditure of one hundred ninety-seven man-days. Material costs: none. Supervisory costs: $86.92.

B. Men Working from Homes

Under this program a total of 5,321 man-days was expended during the period with supervisory cost of $2,776.03. The cost of materials used on the various projects came to $1,051.56.

Field Projects

1. Fences, Construction and Maintenance:

ECW Form-7 No. 131. During the period 335.1 rods of fence were constructed along the Lihue-Koloa Forest Reserve boundary. This fence has been a great assistance in keeping trespassers and live stock from the reserve. Eighty-eight man-days were expended on this project. Material costs: $132.88. Supervisory costs: $49.50.

Under maintenance, 715.1 rods of fence were cared for and placed in serviceable condition. One hundred rods were in the Lihue-Koloa Forest Reserve and 615.1 rods in the Moloaa Forest Reserve. Ninety-six man-days were expended on this project. Material costs: none. Supervisory costs: $23.50.

2. Field Planting and Maintenance:

ECW Form-7 No. 501. During the six-month period a total of 150.1 acres of new planting was completed. Eleven hundred man-days were expended on this work with $560.00 for supervisory costs and no expense for material.

The plantings were divided as follows: Lihue-Koloa Forest Reserve 74.8 acres, Kealia Forest Reserve 14.8 acres, Halelea Forest Reserve 25 acres, and Nonou Forest Reserve 35.5 acres.

Under maintenance a total of 78,688 trees was planted, the main varieties being Acacia, Albizzia, Eucalyptus, and Grevillea robusta. Smaller numbers of several other kinds of trees were planted to test their usefulness under the conditions prevailing at various localities in the forest reserves. The trees were furnished by the Lihue and Kalaheo Nurseries and carried to the planting areas by CCC trucks.

Under maintenance a total of 283.7 acres was cared for with the expenditure of 884 man-days and material expenditures of $5.70. Supervisory costs were $353.33. A total of 117,734 trees was cared for. Due to the unusually dry condition which prevailed generally, the losses were much heavier than generally anticipated. The areas maintained were as follows: Lihue-Koloa Forest Reserve 36.9 acres, Kealia Forest Reserve 98.8 acres, and Nonou Forest Reserve 148 acres.

3. Foot Trails, Construction and Maintenance:

ECW Form-7 No. 206. In the Moloaa and Nonou Forest Reserves 2.4 miles of foot trails were constructed to give access to areas otherwise inaccessible for planting. Man-days expended were 148. Material costs: none. Supervisory costs: $58.50.

Under maintenance a total of 5.4 miles of foot trails was maintained and kept in serviceable condition within the Moloaa, Nonou, Kealia and Lihue-Koloa Forest Reserves. One hundred fifty-seven man-days were expended on this project. Material costs: none. Supervisory costs: $72.00.

4. Horse Trails, Construction and Maintenance:

ECW Form-7 No. 207. Two and five-tenths miles of horse trails were constructed with a total use of 235 man-days. Material costs: none. Supervisory costs: $128.00. These trails were needed to give access to planting areas and to provide a way into the reserves so that the rangers could efficiently patrol the areas. One mile was constructed within the Kealia Forest Reserve and 1.5 miles within the Na Pali Kona Forest Reserve.

Under maintenance a total of 8.8 miles of horse trails was cared for and kept in serviceable condition within the various forest reserves. A total of 1019 man-days was expended on this project. Material costs: $147.54. Supervisory costs: $650.50.

Some sections required the use of a considerable amount of powder work, especially the Haena-Kalalau Trail along the Na Pali Kona Coast where it was necessary to remove a number of rock ledges that obstructed the trail.

Trails maintained within the various forest reserves are as follows: Na Pali Kona Reserve, Haena 4.4 miles, Na Pali Kona Reserve, Kokee 2.2 miles, and Kealia Reserve, Anahola 2.2 miles.

5. Truck Trails, Construction and Maintenance:

ECW Form-7 No. 202. Five-tenths of a mile of truck trail was constructed within the Lihue-Koloa Forest Reserve to give access to a large area in need of planting. One hundred thirty-nine man-days were expended on this project. Material costs: none. Supervisory costs: $64.00.

Under maintenance a total of 5.3 miles of truck trails was maintained and kept in serviceable condition within the Na Pali Kona, Kealia and Lihue-Koloa Forest Reserves. A total of 98 man-days was expended on this project. Material costs: none. Supervisory costs: $45.00.

6. Erosion Control, Planting and Maintenance:

ECW Form-7 No. 307. A total of 4840 square yards of gullies was sloped and planted within the Nonou Forest Reserve requiring an expenditure of 20 man-days. Twelve hundred trees were planted within this area. Material costs: none. Supervisory costs: $9.00.

Under maintenance a total of 33,880 square yards of gully plantings was maintained within the Nonou Forest Reserve. A total of 8195 trees was cleared of

weeds and maintained during the period. Material costs: none. Supervisory costs: $9.00.

7. Foot Bridges:

ECW Form-7 No. 101. One foot bridge was constructed within the Na Pali Kona Reserve over the Halemanu Stream. Material for construction of the bridge was obtained from the immediate vicinity of the stream. Material costs: none. Supervisory costs: $14.50.

8. Structures:

ECW Form-7 No. 120. One glass-roofed, seed-germinating house was constructed at the Kalaheo Nursery requiring an expenditure of 12 man-days. This will aid greatly in the production of plants and trees at the nursery. Material costs: $71.19. Supervisory costs: $10.00.

9. Razing Undesirable Structures:

ECW Form-7 No. 713. One undesirable structure within the Lihue-Koloa Forest Reserve at Wahiawa was razed, eliminating danger of tresspassers and possible fires. All usable material was taken to the Kalaheo Nursery and used in nursery repairs and improvements. Twenty man-days were expended on this project. Material costs: none. Supervisory costs: $9.00.

10. Seed Collection:

ECW Form-7 No. 505. Eighty-four pounds of seeds of various kinds were collected, aiding greatly in the production of trees at the nurseries at a minimum of cost. Sixty-three man-days were expended in seed collection with a supervisory cost of $27.00.

11. Nurseries:

ECW Form-7 No. 503. A total of 1213 man-days was expended on nursery work as follows: Kalaheo Nursery 540, and Lihue, Grove Farm Nursery 673.

Material cost for both nurseries $693.53. Supervisory costs: $498.33.

A report on the output of the two nurseries will be found elsewhere in this report. Both nurseries have been considerably enlarged to fill the needs of the planting requirements of the CCC.

Summary of Work Projects

The following summary includes all work accomplished on projects by the Camp enrollees and Men Working From Homes during the past six months.

1. Planting Forestation:

A total of 91,613 trees, covering 199.1 acres, was planted during the period on government lands within various forest reserves as follows:

Lihue-Koloa Forest Reserve

Acacia dealbata	55	
Acacia koa	222	
Albizzia moluccana	4,544	
Araucaria excelsa	830	
Eucalyptus citriodora	2,175	
Eucalyptus robusta	3,000	
Enterolobium cyclocarpum	1,826	
Grevillea robusta	16,674	
		29,326 trees

Kealia Forest Reserve

Acacia dealbata	80	
Casuarina glauca	2,430	
Eucalyptus citriodora	405	
Eucalyptus robusta	1,583	
Fraxinus americana	49	
Grevillea robusta	52	
Melaleuca amarillis	7	
Melaleuca leucadendron	220	
Tristania conferta	60	
Salix sp.	9	
Spondias lutea	300	
		5,195 trees

Halelea Forest Reserve

Acacia koa	1,374	
Albizzia moluccana	1,300	
Grevillea robusta	3,947	
Melaleuca leucadendron	1,274	
		7,895 trees

Nonou Forest Reserve

Acacia dealbata	135	
Albizzia moluccana	1,155	
Araucaria excelsa	68	
Casuarina equisetifolia	487	
Eucalyptus citriodora	1,000	
Eucalyptus robusta	2,282	
Grevillea robusta	28,741	
Spondias lutea	917	
		34,785 trees

Puu Ka Pele Forest Reserve

Acacia koa	488	
Eucalyptus rudis	810	
Grevillea robusta	13,114	
		14,412 trees

2. Planting Maintenance:

A total of 174,944 trees from previous plantings throughout the various reserves was hoed free from grass, weeds, and brush. A large part of our plantings has been carried on in areas covered with heavy brush and scrub growth; other areas are subjected to heavy rainfall making it imperative that the young trees be cared for at least once every 6 months in order that they may make a normal growth.

3. Erosion Control:

A number of eroded areas and gullies are to be found on reserve lands formerly used as range for livestock. These are usually of no great area but efforts have been concentrated towards planting them with suitable trees which will survive under trying conditions and check further erosion. Trees planted in these areas are spaced 6 x 6 feet to promote rapid closing-in. The Eucalyptus robusta, Casuarina glauca, Grevillea robusta and Acacia dealbata have proven themselves to be of great value in erosion control. A number of photographs included with this report show the growth and results obtained by planting these species on eroded areas.

During the period a total of 4,840 square yards of eroded gullies was sloped and planted with 1,200 trees. In addition 33,880 square yards of gully plantings were maintained within the Nonou Forest Reserve.

4. Truck Trails: (Construction)

(a) *Na Pali Kona Forest Reserve*

Kokee CCC camp	.1 mile	

(b) *Lihue-Koloa Forest Reserve*

Kalaheo plantings	.5 mile	
		.6 mile

5. Truck Trails: (Maintenance)

(a) *Na Pali Kona Forest Reserve*

Kokee—Kumuwela road	5.0 miles	
Kokee—Camp No. 3 road	.6 mile	
Kokee—Camp No. 4 road	.3 mile	
		5.9 miles

(b) *Moloaa Forest Reserve*

Kilauea Arboretum road	.1 mile	

(c) *Lihue-Koloa Forest Reserve*

Kalaheo plantings	.2 mile	
		.3 mile

6. Foot Trails: (Construction)

(a) *Moloaa Forest Reserve*

Fence line trail	1.4 miles	

(b) *Nonou Forest Reserve*
Fence line trail..... 1.0 mile

(c) *Puu Ka Pele Forest Reserve*
Fence line trail..... .7 mile
—— 3.1 miles

7. Foot Trails: (Maintenance)

(a) *Moloaa Forest Reserve*
Fence line trail..... .4 mile

(b) *Nonou Forest Reserve*
Fence line trail..... 2.0 miles

(c) *Kealia Forest Reserve*
Anahola fence line trail..... 2.9 miles

(d) *Lihue-Koloa Forest Reserve*
Wahiawa planting trail..... .6 mile
—— 5.9 miles

8. Horse Trails: (Construction)

(a) *Kealia Forest Reserve*

Anahola River trail..... 1.0 mile

(b) *Na Pali Kona Forest Reserve*
Halemanu Ridge trail..... 1.1 miles
Waininiua Ridge trail..... .4 mile
Puka Ohelo Ridge trail..... .5 mile
Puka Ohelo Kalalau trail ..... 4.5 miles

(c) *Puu Ka Pele Forest Reserve*
Fence line trail..... 4.0 miles
—— 11.5 miles

In addition to the new horse trails completed, preliminary lines totaling 7 miles were laid out and partially cleared to be developed into horse trails during the ensuing period.

9. Horse Trails: (Maintenance)

(a) *Na Pali Kona Forest Reserve*

Haena-Kalalau trail ..... 4.4 miles
Waininiua trail ..... 1.0 mile
Halemanu Ridge trail..... .8 mile
Halemanu Lookout trail ..... 5.3 miles
Halemanu Canyon trail..... 3.0 miles
Kanalohuluhulu-Puka-Ohelo trail ..... 4.0 miles
Nualolo trail ..... 7.5 miles
Milolii trail ..... 2.0 miles
Milolii-Makaha trail ..... 1.0 mile

Alakai Swamp trail	1.0 mile	
Malua-Popoki trail	.5 mile	
Makaha trail	2.5 miles	
Kauhau trail	2.0 miles	
Kopiwai trail	1.1 miles	
(b) *Kealia Forest Reserve*		
Anahola River trail	2.2 miles	
	——	38.3 miles

10. Minor Roads: (Maintenance)

Na Pali Kona Forest Reserve

Kokee	3.2 miles	
	——	3.2 miles

11. Foot Bridges:

One foot-bridge 4 x 40 feet was constructed along a foot trail across a deep ravine at Halemanu, Na Pali Kona Forest Reserve, eliminating a detour of approximately one-half mile.

12. Structures:

A 10 x 16 glass-roofed, seed-germinating house was erected at the Kalaheo Nursery. Previous to the construction of such a building young seedlings were raised in flats out in the open. During the rainy season the mortality of the tiny seedlings was very high, greatly handicapping nursery production.

13. Dwellings: (Improvements)

Improvements were made to the Kanalohuluhulu Ranger Station adjacent to the Kokee CCC camp by covering the exterior walls with heavy building paper and shingles. These improvements will tend to keep out the cold and make the building more liveable during inclement weather.

14. Eradication of Plant Pests:

Approximately 10 years ago a few plants of the Himalaya blackberry were introduced to Kokee and planted there by a lessee of one of the Kokee camp sites. Soil and climatic conditions were evidently ideal for the plant as it grew luxuriantly and soon began to spread by root runners until it has covered a large area forming an impenetrable mass. Seeds of the fruit have been scattered by birds and new plants have been found growing some distance from the mother plant.

To eliminate this plant it has been necessary to cut off all growth above ground and then dig and remove all roots. Young shoots which may appear from roots left in the ground are being sprayed with diesel oil. By this method it is hoped that this pest will be eliminated in due course of time.

15. Nurseries:

During the past six months this work continued at both the Lihue and Kalaheo Nurseries. Six CCC men were employed in this work in addition to the regular

nursery personnel. It has been necessary for both nurseries to enlarge their areas to care for the increased output. Thirty new plant benches were constructed at the Kalaheo Nursery and a 10 x 16 glass-roofed, seed-germinating house was also constructed to care for the young seedlings.

A total of 197,722 seedlings and rooted cuttings was started at both nurseries during the period.

Forest Fires

In the Na Pali Kona Forest Reserve at Kokee four fires were found in early stages of burning and were extinguished before any appreciable damage was done.

Equipment

To date our trucks and station wagons have covered a distance of 135,913 miles. Five Model BB Ford trucks and one Model B Ford station wagon have completed 18 months service and are still in good running order. At the start of the Kokee camp three additional Ford V8 1½-ton trucks were purchased along with 2 Ford V8 station wagons and one Chevrolet ½-ton pick-up truck. Accurate records have been kept on the operating costs of all vehicles, including gasoline, oil, service, repairs, tires, and tubes. The following tabulation shows the operating cost per mile of each vehicle for the past six months.

Station Wagons			*Trucks*		
CCCTH-No.	Model	Cost Per Mile	CCCTH-No.	Model	Cost Per Mile
K-27	Ford Model B	$ .037	K-28	Ford Model BB	$ .039
K-56	Ford V8	.01	K-29	Ford Model BB	.051
K-57	Ford V8	.01	K-30	Ford Model BB	.041
			K-31	Ford Model BB	.032
			K-32	Ford Model BB	.041
			K-58	Ford V8 BB	.019
			K-59	Ford V8 BB	.018
			K-60	Ford V8 BB	.018
			K-61	Chev. ½ Ton	.009

The average cost of gasoline per gallon during the past six months was $ .14, and of lubricating oil, $ .35½ per gallon.

Photographs

At the conclusion of this report photographs are attached showing the various projects, nature of topography, forest cover, etc.

KOKEE CCC CAMP

BY FRANK COX, DIRECTOR

The CCC camp on Kauai is located at Kokee within the Na Pali Kona Forest Reserve at an elevation of 3,640 feet. The Na Pali Kona Reserve covers an area

of 60,310 acres of which 40,420 acres are government land and 19,890 privately owned. The Puu Ka Pele Forest Reserve which borders the Na Pali Kona Reserve a short distance from the camp contains an area of approximately 4,800 acres. The two reserves form a large part of the watershed which supplies water to the sugar plantations, towns, and other interests located on the island. The sugar plantations have spent vast sums developing the water resources within these reserves and draw each day for irrigation purposes and domestic supply, several hundred million gallons of water.

The famous Waimea Canyon, which is a miniature of the Grand Canyon, is located within this region, as is Mt. Waialeale known as one of the wettest spots in the world, having an average annual rainfall of 400 inches.

A portion of the Na Pali Kona and Puu Ka Pele Reserves has been set aside by the government for camp sites. These are leased at a nominal figure. To date there are approximately 100 summer homes located within the Kokee and Puu Ka Pele Regions. All lessees are subject to the rules and regulations of the Territorial Board of Commissioners of Agriculture and Forestry.

The field projects of the Kokee CCC camp are confined to the area within the two reserves. The work already accomplished and work contemplated by the CCC in this region will not only directly benefit the sugar and interests located on the Island in time to come but will make Kokee and Puu Ka Pele a center of tourist attraction by reason of the roads and trails which are being constructed to the various points of scenic interest with which the area abounds.

Work of clearing the camp site started March 4, 1935. The site was cleared of all growth and graded to make room for the various structures. Construction commenced May 17, 1935, and an average force of about 16 civilian carpenters was employed until July when the force was reduced until completion on August 16, 1935.

Buildings

A total of thirteen buildings was constructed in the following order:

1. Three barracks, 36 x 50, as quarters for the enrollees. Latrines are located in the rear of each and the barracks are separated lengthwise by a partition about four feet high. On either side of this partition and along each side of the buildings, lockers have been provided.

2. A kitchen and mess hall, 36 x 75, which also houses the cooks, their latrine and bath and a small storeroom.

3. A recreation hall, 30 x 62, in which a small canteen is also located.

4. A bath and wash house, 12 x 34.

5. A cooler for fresh vegetables was constructed near the kitchen, measuring 12 x 12, and a storeroom, 12 x 14.

6. The foremen's quarters in a separate building, 18 x 32, contains their latrine and bath and a locker for each of the three foremen and two mechanics. It is roomy and comfortable except that it has no ceiling. This means that it is rather cold and permits myriads of bugs and insects to enter under the eaves as it is practically impossible to make a close joint with a galvanized iron roof.

7. The office for the camp Director, project Superintendent, the Quartermaster, also the Quartermaster's storeroom and dispensary, measures 14 x 40, and is ample for the needs of the camp.

8. A cottage containing a bath and latrine and three rooms, 10 x 12, for the above three executives is comfortable and entirely satisfactory.

9. A garage, 40 x 60, in one end of which two tool rooms were constructed. This building is of ample capacity but the drainage around it is poor. Its roof should be guttered. The drainage is being improved as opportunity offers.

10. A small structure to house the two electric light plants—one a small, second-hand Kohler, is used during the day and supplies power for the refrigerator only; the other, a new Delco which handles the load satisfactorily. There is also a small structure, 12 x 14, for the storage of gasoline and oil.

All this construction is of 1 x 12 S1S with battens, T & G floors, with the exception of the garage and outbuildings; and all have corrugated iron roofs; only the cottage for the executives and the storerooms have ceilings. The workmanship throughout is excellent.

Considering that this is a temporary camp, the barracks are very satisfactory. An additional twenty men can be accommodated without any crowding and in an emergency, at least fifty additional men could be quartered.

The mess hall is somewhat larger than necessary and the kitchen is a trifle crowded. An amount has been set aside to cover alterations. It is believed that the kitchen can be enlarged without any expenditure for material. Most of the labor needed could be furnished by the enrollees if this is permissible. However, this alteration is not urgent and it is recommended that it go over to a future period, and, if possible, the amount set up be devoted to the improvement of the water system which is taken up in a later paragraph.

The recreation hall is admirably suited to the needs of the men. There is ample seating accommodations and tables; a large fireplace which is an actual necessity, not an extravagance, as without it, provision would have had to be made for heating the barracks; plenty of reading matter; a victrola and a piano which were donated to the camp by interested residents.

The whole camp as conceived and carried to completion is giving satisfaction and reflects wise and careful planning.

However, it seems certain that some further provisions must be made for heating during the winter months. The mess hall, foremen's quarters, office, and executives' quarters are without heat of any kind. It is believed that five portable kerosene heaters would solve the problem. At this location the temperature at nights during the winter months often drops close to freezing.

Water System

A pumping plant is located about 245 rods from the camp. Water is pumped from a stream to three 5,000-gallon redwood tanks, a distance of approximately 460 feet with a rise of about 126 feet. It then flows by gravity through a 2-inch pipe to the camp, a distance of about 3,600 feet, with a drop of 66 feet more or less.

Although this season has been the driest in years, the water supply has held up remarkably well, although on several occasions it was dangerously low. The plant consists of a 1½ horse power Fairbanks-Morse gas engine and a belt-driven Typhoon pump. This plant runs on an average of from 8 to 12 hours per day, and while in operation, works at practically full capacity. No piece of machinery can stand this severe strain very long.

Camp Grounds

All the camp grounds are graded or filled and wash badly in wet weather. Grass for planting was donated shortly after the camp was occupied, but as the season was extremely dry, it never took root. A second lot was secured and planted and it is doing well. As yet, it offers little resistance to washing. None of the buildings are guttered, and as the rains of late have been heavy, the washing for a time was serious. Now it is under control through ditching. This work was done on the men's own time. Over a thousand shrubs and plants have been planted about the camp grounds and buildings in an effort to make the camp as attractive as possible.

Miscellaneous

The camp was occupied on July 8, 1935, on which date 43 men were enrolled. Enrollments continued throughout the month and on July 31 there was a strength of 94. On August 21 the full authorized strength of 100 was attained and it has remained at this figure to the end of this period.

Racial Classification

Japanese	25	Chinese	3
Portuguese	17	Filipino	3
Puerto Rican	13	Puerto Rican-Spanish	3
Hawaiian-Chinese	11	Spanish	2
Hawaiian	9	Hawaiian-Spanish	1
Hawaiian-Caucasian	8	Filipino-Spanish	1
Hawaiian-Japanese	3	Negro	1

Total....100

This mixture of races is no bar to their mingling in the most friendly manner. There has been only one minor fight and that occurred between men of the same race. To date, there has been no appearance of shirking or malingering. The men do their tasks cheerfully with a minimum of complaining and are always ready and eager to engage in sports as soon as their day's work is over.

The only complaint regarding food was made about the field lunches furnished during the early days of the camp before the kitchen force had been properly organized. There has been no further complaint. The menu has been constantly improved and that it is ample is proven by the fact that every man has gained in weight from a few pounds to as much as twelve. Providing prices do not rise too much, the ration allowance is ample.

The conduct of the men while on leave has been good. Only one man has gone A.W.O.L. and not a single man has returned from home under the influence of liquor.

Men retained for strictly camp duties number thirteen. While their duties may be somewhat more pleasant than those on field duty, they are practically all men of special training, and at times are hard put to keep their work up to date. It is hard to see how the camp could be run efficiently with a less number. During the month of July, the number of men retained for other than routine camp duties averaged 13.9. The men were at work building up a wood supply. For August, this was reduced to 9.6, and for September, to 3.6.

The general health of the men has been on the average, good. There has been no serious sickness or accident. The most common complaints are colds and sore throats. There has been quite a number of minor accidents in the fields and on account of sports, but accidents from both these sources are diminishing.

The supervisory personnel have without exception rendered honest, intelligent and conscientious service.

ATHLETIC AND RECREATIONAL ACTIVITIES

BY KURT NYSTROM, QUARTERMASTER AND RECREATION OFFICER

Baseball: On August 25, 1935, a meeting was called for the planning of the CCC baseball team. Fourteen players were picked. George Ana was elected captain and third baseman and David Johnson, one of our mechanics, was elected to coach the team. Mr. Johnson was particularly well suited for this task, having been a prominent baseball player in his youth.

All baseball practice was held on the CCC camp home field. The field was levelled off by volunteers after working hours. The players have been practicing diligently and enthusiastically.

Five games were played during the month of September and I am sorry to report that of the five games played, only one was won, score, 8 to 5 in our favor. The fourth game was a close one, our team losing 6 to 5. However, I believe that a change of altitude and climatic conditions should be taken into consideration. During the games played, the heat in the Kekaha and Waimea districts was terrific. We hope that with a little more practice, we shall be able to show better results in the ensuing season.

The baseball team lost a number of good players when our football team was formed.

Five baseball bats and 12 baseballs were purchased from the profits of our canteen. After each game the teams were treated with soda water purchased through the canteen fund. The camp has been furnished, through government funds, with one catcher's mitt, one body protector, one face mask, one first base mitt, seven fielders' gloves, seven baseball bats, and twelve baseballs.

Basketball: The first meeting for the plans of the basketball team for the CCC camp was held August 23. Twelve members of the team were elected. Arnt Anerson, one of our mechanics, was appointed manager of the team. A field

captain is elected before each game. The first practice of the basketball team was held in the Waimea Community Hall on Wednesday, August 28. Future practice is to be held weekly on Wednesdays and Fridays until the league opens.

The present equipment of the team is a basketball purchased through the canteen at a cost of $6.38. Additional equipment is required, such as, basketball shirts and trunks and an entrance fee of $17.50 must be paid for the use of the Hall and as an entrance fee into the league. The estimated cost for additional equipment and fees is $45. The schedule for the games has not yet been completed. No games have been played but a scrimmage game with the Waimea Japanese team was played Friday, September 13. The score was 68 to 17 in our favor. Excellent floor work and frequent baskets have placed the team in a favorable position.

The team ought to have an excellent chance in the coming games.

Football: A meeting was held on September 16, 1935, to form our CCC football team. Twenty-eight players including two rub-down boys and a water boy and one timekeeper were elected. Our team plays barefooted and has entered a 125-pound football league.

All practice is held at our home field every afternoon after working hours. The boys have shown a spirit and an enthusiasm which is quite gratifying. Two games have been played and won. The score of the first game was 13 to 6 and the last game was a very close game with the score 6 to 5. Three more games will be played before the season is over.

It is a keen pleasure to report the splendid team work displayed and the remarkable results obtained when you consider the fact that our team won its first game against experienced and seeded players. Our outstanding players are hard to pick as the team work and cooperation is excellent.

I wish especially to mention that Samuel Smith Jr., one of our foremen and my right-hand man in athletics, has done excellent work and has proven himself a most loyal and efficient co-worker.

Future needs for athletic equipment will, as far as we are able, be taken care of by a combined canteen and company fund.

Recreational Activities

Glee Club: Our Glee Club was organized September 10, 1935, and consists of the following singers:

1. John Kamanuwai, Leader and Bass
2. Samuel Naumu, Tenor
3. Moses Gardner, Tenor
4. Abraham Huddy, Tenor
5. Abraham Williams, Baritone
6. Benjamin Paik, Bass
7. Edward Hilo, Tenor
8. John Akana, Bass
9. David Hopa, Baritone
10. Alfred Au, Baritone

The Glee Club has already been able to perform and to show their ability in front of invited speakers. Further practice will still more improve their singing.

Orchestra: Our string orchestra was organized August 25, 1935, and consists of the following:

1. William Abreu, Leader and Steel Guitar
2. Joseph Chu, Guitar
3. Benjamin Paik, Tenor Guitar
4. John Kamanuwai, Guitar
5. Joe Kaneakua, Ukulele
6. Samuel Naumu, Guitar

Like the Glee Club, our Orchestra is doing excellent work and has also been displaying their talents in front of visiting speakers. Our Orchestra will also be used for playing at our own dance which has been planned for the camp in the future.

Moving Picture Shows: The enrollees of the camp are privileged to attend one moving picture show per week. Usually Friday evening is reserved as a movie night.

The owners of Kekaha Theater and Waimea Theater have shown a fine spirit of generosity in allowing the camp 25 per cent of the collections on the ticket sales, which has been highly appreciated by all concerned.

Camp Canteen

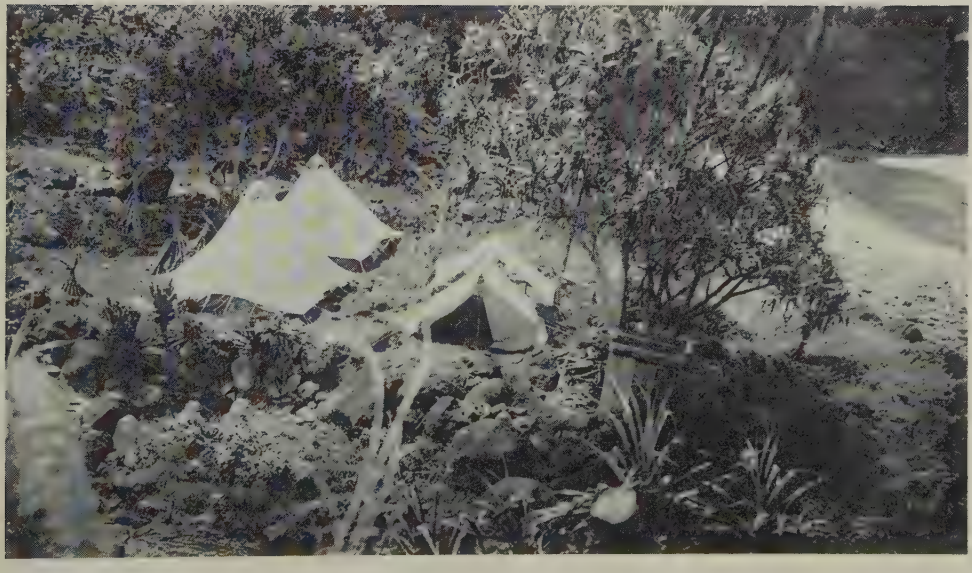
Our camp canteen was started August 22, and the net profit from this short period, August 22 to August 30, 1935, amounted to $13.61. The month of September showed a net profit of $44.12.

All profits derived from the canteen will be used to purchase athletic equipment and eventually finance our dance. It is gratifying that our canteen, small though it is, shows such good profits.

Benefit Dance: A benefit dance is in prospect and will take place on October 26 at the Waimea Community Hall. All profits derived from this dance will be used to purchase equipment for our football team.

Albert W. Duvel, *Associate Forester.*

CCC Camp—Kokee.



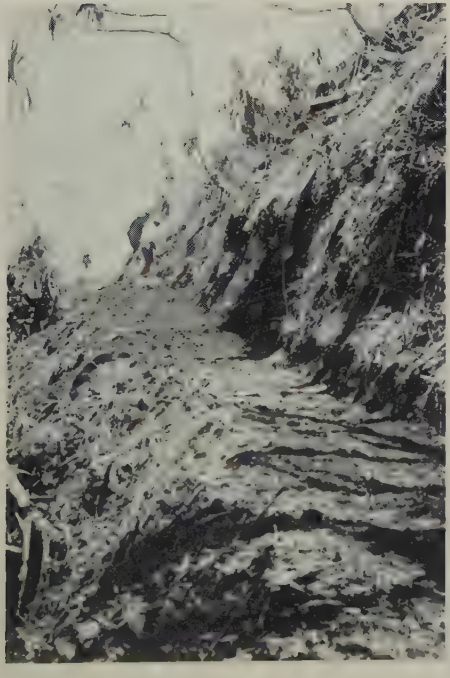
Sub-Camp—Hanakapiai, Haena-Kalalau Trail.

Horse Trail, Haena-Kalalau.

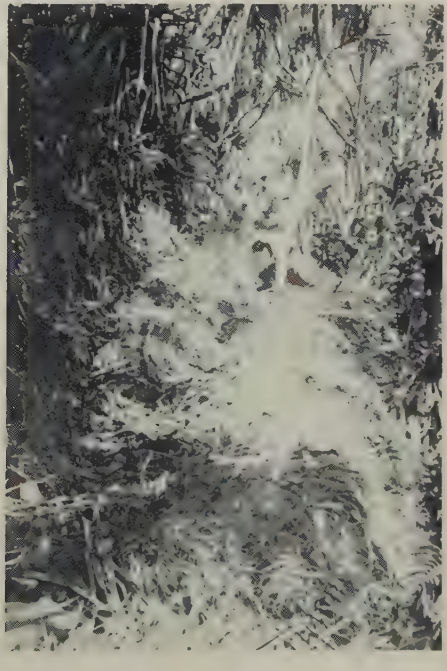
Horse Trail, Haena-Kalalau.

Na Pali Coast along Haena-Kalalau Trail.

Horse Trail, Haena-Kalalau.



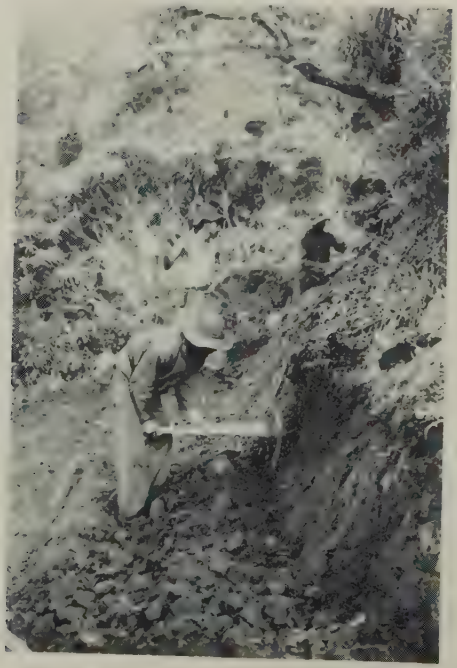
Horse Trail, Haena-Kalalau.



Horse Trail, Haena-Kalalau.

Horse Trail, Kokee.

Horse Trail, Kokee.



Horse Trail Construction, Halemanu-Kokee.

Truck Trail completed, Kokee.

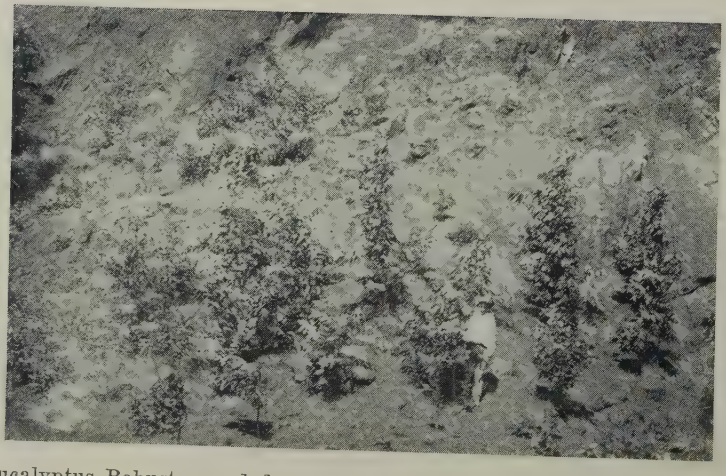
Acacia Koa, Lihue-Koloa Reserve,
age 14 months.

Eucalyptus Robusta, Lihue-Koloa Reserve,
age 12 months.

Melaleuca Leucadendron, Lihue-Koloa Reserve,
age 14 months.

Acacia Dealbata, Lihue-Koloa Reserve,
age 15 months.

Grevillea Robusta, Lihue-Koloa Reserve, age 12 months.



Eucalyptus Robusta, eroded area, Lihue-Koloa Reserve, age 15 months.

Albizzia Moluccana, Lihue-Koloa Reserve, age 12 months.

"Uluhi" Fern closing in on fence line and road, Lihue-Koloa Reserve.

A Brief Resume of Papers Presented to the Agricultural Section of the Fifth Congress of the International Society of Sugar Cane Technologists

By R. J. Borden

A short review of some of the papers that were presented before the Agricultural Section of the International Society of Sugar Cane Technologists at its fifth congress held in Brisbane, Queensland, Australia, August 27 to September 3, 1935 is here presented.

The meetings which convened under the leadership of Dr. H. W. Kerr, Director of the Queensland Bureau of Sugar Experiment Stations, were attended by men whose names are familiar to many of us, and among those present at the reading of the various agricultural papers were the following:

M. S. Moody-Stuart	(British West Indies)	W. J. Maze	(Hawaii)
M. A. del Valle	(Puerto Rico)	W. P. Alexander	(Hawaii)
Dr. P. C. Bolle	(Java)	R. J. Borden	(Hawaii)
Dr. O. Posthumus	(Java)	A. F. Bell	(Australia)
H. W. Dodds	(South Africa)	Dr. A. J. Gibson	(Australia)
R. G. T. Watson	(South Africa)	H. F. Clarke	(Australia)
T. S. Venkatraman	(British India)	C. R. Von Stieglitz	(Australia)
L. Hirachand	(British India)	B. Tapiolas	(Australia)
W. E. Dickinson	(Cuba)	D. S. North	(Australia)
J. Carreras	(Peru)	K. R. Gard	(Australia)
W. S. Taggart	(Louisiana)	E. J. Barke	(Australia)
Dr. C. A. Browne	(Washington, D. C.)	N. J. King	(Australia)
Dr. E. W. Brandes	(Washington, D. C.)	D. L. McBryde	(Australia)
Dr. J. Matz	(Washington, D. C.)	F. E. Clarkson	(Australia)

"Report of the Committee on Labor Saving Devices:"—by W. J. Maze

This report covered the latest developments in machinery and methods being used in various sugar-producing countries to economize on the labor involved. Special mention is made of the use of the Gyrotiller and of the Rotary Hoe, operated by large Diesel tractors, to prepare fields for planting. For land ditching, the Sudan Ditcher is available, while for leveling the land, we have elevating graders and automatic scrapers which can move a lot of soil economically. Planting machines, both small and large, and of many designs are extensively used. Weed control by mechanical means has brought out many designs of cultivators—the spring-tooth type, the disc type, the rotary hoe, and the spinner—all finding their adherents. Chemical weed control has its place but is generally considered somewhat costlier than mechanical means. The use of the siphon pipe to speed irrigation is mentioned. The rather slow development of good fertilizer distributing machinery is cited. The application of filter cake by further diluting it with water so that a filter cake sludge can be pumped through slip-joint pipe to the desired place in the field, offers a cheaper way to distribute this by-product. The more recent developments in cane

harvesting machines are discussed; the perfect machine is still to be found. Mechanical cane loaders are highly successful. Transportation of cane by motor trucks fitted with semi-trailers may offer an attractive low cost operation for this part of the field work.

"Caneland Cultivation in Queensland:"—by N. J. King

Disc plows which are designed to plow under green manures and crop residues, have a piece of spring steel attached that compresses the trash while it is being cut by the sharp discs. In general, the land is plowed three or four times before planting. Often a "grubber" or subsoil knifer is used where the subsoil is compact. The rotary hoe is popular for destroying old stubble, and it has also been used to chop trash and tops prior to plowing them under. Tandem disc harrows are used between plowings. The smaller horse-drawn planting machines drop and cover the seed in a furrow that has been previously opened with a double moldboard plow; the larger planting machines drawn by a tractor open the drill, drop the seed and cover it. Fertilizer attachments are fitted to some of the planting machines.

Cultivation of plant cane has for its objective the elimination of weeds while they are small, and the avoidance of hand hoeing. A straddling disc implement fitted with a rake attachment for cultivation in the cane row is quite generally used. Plowing with a small plow and following with a "spinner" does an effective job. Small interspace rotary hoes are available.

When ratooning is practiced, trash is in some instances burned and thereafter tandem disk harrows are used to mulch the surface soil and to destroy the uppermost eyes of the cane stubble (which ensures a ratoon crop that originates from the lower dormant buds). The stubble-shaver may be used to level the land where cane rows of the plant crop have been ridged or hilled up too high. Where soil moisture is adequate, the stubble is off-barred; during dry weather the grubber is preferred for putting the soil in condition for rapid development of young ratoon roots. Where trash is not burned, it is generally rolled into alternate interspaces, either by hand or by a side-delivery rake.

"Gyrotilling at Aguirre, Puerto Rico:"—by A. L. Foss

This paper includes a description of the work which the gyrotiller can do and is doing in Puerto Rico, and a report of its operating costs. The author states "our experience with the gyrotiller is very favorable in that it does the work for which it was intended and at a very cheap cost."

"Symposium on Methods of Maturity Determination:"

A. *In Barbados*—by G. P. Stevenson

Maturity experiments are conducted at two stations which represent the low- and high-rainfall regions respectively. From three to eight seedlings and two standard varieties are included each year. The randomized block layout is employed, each variety being replicated 18 times. Each plot comprises 16 stools, the test is harvested at three periods during the crop season—early, medium, and late—and six

plots are cut at each harvest. Weights are obtained in the field and the numbers of sound and rotten canes of four arbitrary age-classes recorded. Sample bundles of 100 pounds of cane from each plot, made up of canes of the four age-classes in the ratio in which they occur in the field are milled to determine sucrose in juice. The work results in the allocation of new seedlings to their most favorable environment and the recognition of early- and late-maturing varieties.

B. *In South Africa*—by H. H. Dodds

The principal canes are sampled and tested for purity and sucrose, and also for the reducing-sugar ratio, at intervals of one month, starting in April, which is the beginning of the ripening season.

The hand refractometer has not been found reliable.

C. *In Queensland*—by H. W. Kerr

Ten sticks of cane per field, selected at random, were collected at two-weekly intervals. These sticks were divided into three equal lengths to make three samples for crushing. The juice was analyzed for Brix and polarization. At maturity, the Brix of the juice from the top and butts is practically identical and about one unit below that for the middles. When deterioration supervened, the Brix of the butt declined most rapidly, followed by that of the middles; too often this reversal of Brix values is delayed and the cane is highly over-mature before it is detected. Small analytical discrepancies often cause erroneous conclusions.

The polarization determinations followed the Brix values very closely, although the range between extreme values for several sections of the stalk was greater. Over-maturity is immediately reflected in substantially reduced polarization values. Polarization is a better criterion than Brix.

Reducing sugars are the most reliable single value for estimating the state of ripeness of the crop. The range of variation from immature cane to maximum sugar content is practically 100 per cent and the value decreases from 5 per cent to 0.1 per cent. A well-defined minimum value, uniform for all sections of the stick, is recorded at maturity. Over-maturity is revealed by a sudden and substantial rise in the reducing sugar content of the juice from the butt sections.

Dr. Kerr presents the details of a rapid and accurate colorimetric method for determining reducing sugars, and a formula by which the sugar content may be estimated from the Brix and reducing sugars. He suggests that sampling may be confined to the top and butt sections only.

D. *In India*—by B. Viswa Nath

The top/bottom ratio, with a suitable sampling technique, is generally satisfactory. The basis of this ratio concept is that as the cane ripens, the concentration of total solids in the juice of the top and bottom halves of the cane tends to approach unity. Since under field conditions it is the practice to top a few joints above the highest dead leaf, maturity is indicated when the top/bottom Brix ratio is 0.95. With over-ripeness, the ratio increases beyond unity.

The biggest sources of error are the nature and size of the sample and the expression of the juice. The plots are sampled at the rate of 60 to 80 canes of each variety, selecting *whole* clumps from equidistant spots. Each cane is cut into halves, roughly, and the bottom and top halves crushed separately, care being taken to avoid large variations in the feeding of canes to the mill and in the pressure of the crushing rollers.

"Cane Trash and Soil Organic Matter:"—by C. R. von Stieglitz

The experiments reported were conducted with three different soil types, with and without additions of cane trash, in pots under controlled conditions. After a decomposition period of 10 months, the actual gain in terms of available moisture due to trash treatment is 17 per cent. The reduction in "apparent density" and "volume expansion" on wetting are effects of the trash. During the decomposition, 54 to 71 per cent of the carbon was lost as CO_2. An increase in available phosphoric acid was recorded for the trash treatments, and the proportion of added soluble phosphate that was fixed by the trash-treated soil was less. Increased amounts of calcium and magnesium in trash-treated soils were greater than amounts added in the trash. Trash did not cause increased acidity, in fact, the reverse was true. There was an enormous increase in the count of soil microorganisms due to the presence of trash.

"Symposium on Methods of Selecting Seedlings:"

A. *In Barbados*—by A. E. S. McIntosh.

Of the 20,000 seedlings potted, 10,000 are planted-out in the field. Selections have been made from these at 10 to 12 months, but new plans call for this to be done at 15 to 17 months. Progeny of crosses, which have shown a high percentage of good seedlings in the past, are harvested twice during the crop—early and late. Those with satisfactory weights are divided into two bundles, one of which is milled; from the data thus obtained, about 10 per cent of the canes are retained; the other bundle furnishing the seed for planting in multiplication plots.

B. *In Puerto Rico*—by R. L. Davis

Preliminary selection of true hybrid seedlings is made from the germination flats. Those chosen go into the field nursery, being planted in groups of four on the corners of 6-inch squares, spaced one foot apart in rows that are 2 feet apart. At the age of three and one-half months, the best one of each 4 is chosen and the others discarded. The best 5,000 to 10,000 seedlings in this primary nursery are planted in secondary nurseries following the same "planting square" system, but with wider spacing, i. e., planted on the corners of a 2-foot square with the squares spaced 4 feet apart each way. A secondary elimination is also made so that only one seedling in 4 is retained. Final elimination is made at maturity on the basis of weights and juice analyses.

During the second year, the stooling habit and sucrose content are studied in comparison with interplanted standard varieties. During the third year, seed supplies are increased and those of promise are sent out for orientation tests. Final field trials are conducted with at least 10 replications in one-tenth acre square plots.

C. *At Canal, Point, Florida, U.S.A.*—by G. B. Sartoris

A detailed study of the agronomic characters and the use of a score card for selecting superior progenies are features of the Florida selection work. The breeding value of parents is carefully determined. The complete progenies from the best crosses are sent to the major sugar cane areas and tested for resistance to various diseases.

D. *At the Florida Experiment Station, U.S.A.*—by B. A. Bourne

Potted seedlings are set in the field four feet apart in furrows eight feet apart. This wide planting is to facilitate judging at maturity, since most of the canes are recumbent at this time. First selections are made on the basis of resistance to disease, good agricultural habits, and Brix. These go into line tests with two or more control canes on the two main soil types in Florida. When eight to ten months old, ten stalks are removed at random from each plot and milled. All high-testing types are again analyzed as a further check. This first series of analyses aims to discover the early-maturing types. Some three months later, a second series of analyses aids in locating the late-maturing forms and gives further data on the stability of sugar and purity of the early maturers. Final selection is not attempted until the varieties are judged and scored on their agricultural qualities and disease resistance. Since there are no replications, no weights are taken but an estimate of low, medium, or high tonnage is made by visual comparison with the control canes.

During the second year, single plot tests are established on the two main soil types. Weights and analyses are compared with the control canes at about 12 to 13 months of age, and corroborative evidence of the plant cane results is secured. The superior canes then go into replicated tests, wherein twelve replications of one-tenth acre plots are used.

E. *In Mauritius*—by A. Glendon Hill

About 75 per cent of the seedlings potted are planted-out, some at 1,000 feet elevation and some at 200 feet. At the age of one year the early-maturing seedlings are selected. The late maturers are selected at 15 to 20 months. In these selections, the healthier seedlings with good growth habits are chosen and tested for Brix with the hand refractometer. The better ones are cut and weighed, and selected for further trial. About one per cent are retained for this trial.

The second trial consists of comparing nine selected canes and one standard cane in 10-hole Latin Square layouts. The best canes from the second trial go into a third trial, being planted in randomized blocks, each plot of which consists of 3 rows of 7 holes each, and from which the center row only is harvested. These third trials may be ratooned if the varietal competition is not obvious. At the time of these third trials, cuttings of each seedling are planted in gummosis-resistance trials. Final field trials are designed so that the two outside rows of each plot are discarded at harvest.

F. *At the Colonial Sugar Refining Company*—by H. F. Clarke

(1) In *Fiji* seedlings are planted-out when 3 to 4 months old, being spaced 5 feet apart each way. For every 10 rows of seedlings there is a row of a standard variety. First selection is made at 17 to 18 months and is based on disease resistance and agricultural qualities. Up to 5 per cent are chosen for further planting in plots of 3 rows, 12 to 20 feet long, and one or more standard varieties are planted with them. The second selection is made at 15 to 20 months. A stool of each variety is cut every month from June to October to secure a ripening curve. The yield is estimated. Further selections are planted in randomized plot trials with one or more standard canes. These are cut at 17 to 18 months, weighed and analyzed. Border rows and end stools in the rows are excluded at harvest. The plots are ratooned.

(2) In *Queensland* the basis of selections is the same as that in Fiji. First selections are made at 13 to 14 months and those chosen go into a 12-foot row, with a standard cane to every 3 seedlings. They also go into a gum-resistance trial. The second selection is made at 12 to 13 months, on the basis of the gum-resistance trial, on total solids and polarization of small mill samples, and on vigor and growth habits. The next trial is in a plot of six 12-foot rows with a standard variety in every tenth plot. At 12 to 13 months selection is made on yield and juice quality for final testing in randomized plot trials.

G. *In Queensland*—by E. J. Barke

The basis of selection is resistance to disease. At least 100 seedlings are selected at random from all vigorous crosses and included in a "family" resistance trial.

Potted seedlings are planted-out at 3 to 4 months in rows 5 feet apart, with 3 feet between seedlings. Preliminary rejections are made at 10 to 11 months and final selection at 12 months. Selection is based on vigor and habit and on refractometer tests which must not be 2 to 3 degrees Brix below that of the standard cane. About 1 per cent of the total is selected.

In the second year, single row plots of 5 to 10 stools each are interspaced with a row of the standard cane. Complete juice analyses are secured at harvest. From the results of the second year, checkerboard observation trials are laid down. Maturity tests are conducted, and yields secured. These plots are ratooned to determine ratooning qualities. Selected seedlings go into farm trials on various soil types in their fifth year. A Latin Square or Randomized Block layout is used for these farm trials.

H. *In India*—by T. S. Venkatraman

Lists of suitable and undesirable parents are compiled from the type of hybrids grown each year. Large numbers of seedlings (100,000) are raised from the desirable crosses. These are planted in beds 12 by 6 inches apart. The more vigorous are picked out and planted as in the ordinary cultivation practice and grown for a full year. Juice analyses are made of only those which show the desirable vegetative characters; the rest are discarded.

These selected seedlings together with standard canes are then planted in 20-foot rows. Notes are kept on germination and habit, and a periodic study is made to estimate vegetative growth and root development. Periodic weighings of the above-ground parts and root dissections *in situ* are made. In selection work, canes chosen in bad years are found more useful than those selected in good years because such canes possess a wider sphere of usefulness. Juice analyses of each seedling are made at the beginning, at the end, and at two intermediate times during the crushing season. For each analysis, a *whole* row is cut and treated as a sample. The soil, manurial and other conditions of the testing areas are never allowed to be better than the prevalent conditions in the locality.

The selection work stresses attention on the comparison of new canes with the standards periodically throughout their growth; how they stand the critical periods and take advantage of favorable periods for growth. This enables selection to be made with some confidence.

I. *In Hawaii*—by A. J. Mangelsdorf

The use of a weak solution of sulphur dioxide and phosphoric acid to keep cane tassels alive is a big feature of the breeding technique in Hawaii. Male and female tassels for the desired cross are cut and transported to a protected area away from the likelihood of contamination from undesired pollen. Here, four female and six male tassels are set up in five-gallon pails that hold the solution which is changed at intervals of two or three days. Within ten days the male tassels are discarded and the females removed to a "ripening area," where they are watched until the "fuzz" is ready to harvest.

Seedlings are transplanted to flats when they are several inches tall; later, when about a foot tall, they are planted-out in the field in four-foot rows, being spaced one foot apart in each row. Selection is made at about 8 months, and cuttings of those desired are planted in a 10-foot row adjacent to 10 feet of a standard variety. This preliminary trial is harvested at 12 months and cuttings sent to the "regional stations" for further testing. Those which show promise are eventually distributed for final yield trial in replicated checkerboard plots.

In the primary selections, no yields are taken but selection is made on qualitative characteristics. Disease resistance is watched for. Brix readings are taken at each stage of selection in both plant and ratoon plots. Thus some 15 to 30 Brix comparisons of the seedling and its adjacent check or standard cane are secured, and fairly reliable conclusions with reference to sucrose are thus obtained.

"Irrigation in the Lower Burdekin District:"—by B. Tapiolas

There are 527 irrigation units operating in this district, pumping some 630 million gallons of water from sand beds which underlie the cane lands perhaps only 10 to 40 feet below the surface. By driving "spears" into this water-bearing sand and connecting a number of these "spears" to a pumping unit, it is possible to secure a good supply of water free of sediment.

Irrigation of the young cane is delayed as long as possible, due to the character-

istic nature of the soils to run together and become compacted by irrigation. In the early stages, water is applied in the cane furrow. Surface cultivation follows as soon as possible and this necessitates reshaping the lines for subsequent irrigations. As the crop develops the lines are filled in, the cane is hilled up, and the water furrows thereafter occupy the interspaces.

The length of furrows varies with the nature of the soil, and on some soils is as long as 1,000 feet. Water is taken from the supply ditches through 2 x 24-inch galvanized iron pipes at the head of each line. Three-inch applications are desirable, with intervals of 10 to 12 days when necessary.

"Drainage Methods in Fiji:"—by H. F. Clarke

Artificial drainage is essential on many lands in Fiji. The open-ditch system prevails. There is a ditch around the field that is 3 to 6 feet deep into which internal ditches, 125 to 250 feet apart, empty. Flood gates are necessary to keep tide waters out. The ditches are costly to maintain and reduce the cane area available.

Mole drains have been successfully used where the texture of the subsoil was suitable. They were effective for about 8 years, when they were deep enough to escape damage from cultivation implements. Recently tile drains have been used. These were set about 265 feet apart, about 3 feet below the surface. Generally speaking, this tile draining has not increased yields but it has made all field operations easier, eliminated the maintenance of open ditches and made 4 to 5 per cent more land available.

"Surface Drainage in the Mackay District:"—by F. E. M. Clarkson

The poorly drained lands are flat and have many saucer-shaped depressions, some 6 inches below the surrounding land level. The subsoils are relatively impervious. Stands of cane are poor and growth is unsatisfactory. Thus we find that open surface drains, 20 feet wide and deepened to the clay subsoil, are run across the lower end of the field and graded to deliver water to a main drain thence to swamp or creek. Other 20-foot drains along the headlands run with the main slope and deliver to this lower drain. Soil removed from these drains is used to fill depressions in the field. Drains are made broad and flat so that cultivation implements can cross them without difficulty. As a further precaution cane may be planted in beds that carry 14 to 18 cane lines running in the direction of the greatest slope, with 10-foot water furrows left between these beds.

"Variation Within a Clonal Population:"—by A. F. Bell

Variation in the number of stalks per stool may be due to variations in type and density of the microbiological flora, the rate of application of fertilizer, physical condition of soil, depth of cover placed over the seed piece, overcrowding by adjacent stools during growth, and variation in growth capacity within the visually equivalent seed pieces.

"Determining Theoretical Yields of Sugar in Connection with Variety Tests on the Basis of Field Sampling and Laboratory-Scale Milling Tests:" —by George Arceneaux.

Separate juice analyses must be available from each individual plot, if statistical methods are to be used to study sugar yield data. Where small plots are used and the total amount of cane is small, ordinary factory milling is impractical, hence the necessity of experimental milling equipment.

Studies on methods of field sampling indicate that best results are obtained when cane samples for milling are taken at random from the entire area of each plot after cutting.

Plots are one-fortieth acre in size and the test carries 12 replicates in a Latin Square arrangement. At harvest, 40 to 50 stalks are selected at random from each plot for milling in a 3-roll power-driven mill that gives an extraction of about 60 per cent. Individual averages based on 12 such determinations are sufficiently accurate to permit the measurement of differences of 5 per cent or more in yield of sugar per ton of cane.

"The Maintenance of First-Year Characters in New Sugar Cane Clones:"—by A. G. Hill

Weight-per-stool is probably exaggerated in first-year seedling selection and it is suggested that new seedlings be allowed to settle down for one or two seasons in order to allow exaggerated vigor to abate, and give undesirable traits a chance to appear before attempting to assess quantitative characters.

"Queensland Cane Variety Census 1934:"—by J. M. MacGibbon

This census shows the percentage of sugar tonnage obtained from different varieties grown in Queensland. Badila leads the list at 36.8 per cent, followed by M 1900 at 9.8 per cent, H. Q. 426 at 7.5 per cent, E. K. 28 at 6.8 per cent, D 1135 at 6.1 per cent, Q 813 at 5.6 per cent, H. Q. 409 at 4.9 per cent. Both Uba and POJ 2878 contribute 1.3 per cent and H 109 is down at .05 per cent.

"Report by the Committee on Soils:"—by O. Schreiner

This committee has assembled a bibliography of soil and fertilizer literature, listing all publications which have appeared in the period 1931-1933 which supplements the list presented at the Fourth International Congress of Sugar Cane Technologists.

"Symposium on Laboratory Methods of Soil Fertility Determination:"

A. *In Mauritius*—by N. Craig

The methods used are field experiments which are the basis for all other methods, and chemical laboratory methods and physiological methods in field and laboratory which are more rapid and easily performed.

Organic carbon in soil samples is determined by a modification of the method of Schollenberger. Both Truog's and Dyer's methods are used to determine phosphates. Exchangeable base is determined by the method of Bray and Wilthite.

Phosphate in the juice is determined by the colorimetric method of Denigés; potash in the juice by the Oliver method.

Details of all these methods are given.

B. *In Barbados*—by Dr. S. J. Saint

The correlations between juice and cane analyses are very high, and show that a juice analysis will be a good comparative indication of the analysis of the cane as a whole.

Approximately 62 per cent of the total potash, 53 per cent of the phosphoric acid, 41 per cent of the total ash, and 40 per cent of the nitrogen present in the whole cane were expressed in the crusher juice from a 3-roller mill that gave approximately 70 per cent juice and 30 per cent bagasse, by weight.

The report concludes that juice analyses are of little value in determining possible soil deficiencies because varieties differ in their absorption of potash from the soil, and climatic conditions affect the absorption of phosphoric acid particularly.

C. *In Queensland*—by H. W. Kerr and C. R. von Stieglitz

A modification of Truog's method for determining available phosphoric acid is described. When correlated with results of field trials, it appeared that 80 per cent of those soils showing more than 35 p.p.m. gave no significant response to applied phosphate, while 84 per cent of those with less than 35 p.p.m. showed a definite response.

Replaceable base determinations are not considered sufficiently precise as a test for potash availability. The greatest value of the method lies in its ability to indicate those soils on which potash fertilization can be expected to show negative response. Above a limiting value of 0.18 M. E., 84 per cent of the soil samples were from trials which failed to respond to potash fertilizers.

D. *Rapid Field Tests in Queensland*—by C. R. von Stieglitz

Rapid tests devised by Morgan have been used on a series of 39 type soils. The method for phosphate was not satisfactory, and it has been modified so that a better agreement is being obtained. Two well-defined groups—high and low—of potash can be differentiated by the turbidity test. Nitrate and ammonia nitrogen tests are sufficiently indicative as to be of distinct value.

"Methods Used to Determine the Fertilizer Requirements of Sugar Cane in Louisiana:"—by A. M. O'Neal and L. A. Hurst

A reconnaissance soil survey is first made in order to determine the principal soil areas, soil series, and soil types. This makes for a broader interpretation of the data obtained.

In selecting the test areas or plots for experimental purposes, a careful soil survey is made of that part of the plantation where the test is to be located. The plots are then laid out to the best advantage on the particular soil type that is to be studied. This location of different soil-type boundaries is considered essential to reliable results.

The individual plots consist of four rows and are one-sixtieth acre in area. Only the two center rows of each plot are harvested. Cane is weighed in the field and while weighing, sample stalks are drawn at random to make a 50- to 60-pound bundle that is milled in an experimental mill.

"Fertilizer Studies on Two Important Soil Types in Louisiana:"—by A. M. O'Neal, O. Schreiner, and L. A. Hurst

Results of these studies indicate the amounts of plant food for optimum yields and the best combinations of N, P_2O_5 and K_2O for the total plant food used.

"Methods Used by the U. S. D. A. in the Analysis of Sugar Cane Juice:"—by N. McKaig, Jr., and L. A. Hurst

When fertilizer experiments are harvested, a cane sample of 50 to 60 pounds of mill-length cane is crushed in the experimental mill. The juice is passed through a 1 mm. sieve and then centrifuged for 7 minutes against a force of 2,300 times gravity. This eliminates suspended material without altering the concentration of soluble materials.

Various analytical procedures are discussed.

"A Study of Sugar Cane Stalk Age Groups Under Louisiana Conditions:" by George Arceneaux

This report summarizes the results of studies conducted on shoots and millable stalks of 10 cane varieties divided into 4 groups according to their period of germination.

The rate of mortality was approximately the same for mother shoots and suckers originating before April 20 and after this date.

A definite relationship as to average weight per stalk was revealed for the different age groups. Arranged in descending order of stalk weight are (a) suckers originating between April 11 and May 29, (b) suckers originating prior to April 11, (c) suckers originating after May 29, and (d) mother stalks. Group (c) suckers averaged about 10 to 13 pounds of sugar per ton of cane less than other groups.

"Mechanical Help for Field Sampling:"—by F. D. Stevens

Platform scales are mounted on skids and hauled by a three-quarter-ton truck that carries a portable mill geared to a small engine. The scales carry a basket platform that holds about 300 pounds of cane and is easily tipped.

The use of this portable mill eliminates the hauling of cane samples to the mill. The selected 50- or 60-pound cane sample is crushed and a 2-pound juice sample placed in a copper cylinder for transportation to the laboratory.

"Special Three-Roller Mill Used in Experimental Field Work:"—by O. Schreiner and N. McKaig, Jr.

A description of this mill, together with comments on its efficiency, and data concerned with its comparison with a large commercial mill are given.

"Report of the Committee on Field Experimentation:"—by H. W. Kerr

The report discusses at considerable length the theoretical principles concerned with field experimentation. It calls attention to variation, and explains the frequency distribution curve and other basic facts concerned with an introduction to statistics. It discusses "Student's" method and Fisher's method, paying considerable attention to the analysis of variance and the use of the Latin Square and Randomized Block arrangements.

Such phases as the number of replications, the size and shape of plots, border effects, arrangements of plots, and the determination of plot yields and juice analyses data are also discussed.

"Plot Technique in the Testing of Sugar Cane Varieties:"—by C. G. Lennox and A. J. Mangelsdorf

An optimum plot size of one-tenth to one-fifth acre is suggested for heavy yielding canes. The effect of competition along the plot borders is far-reaching and yields on smaller plots may be misleading. Attention is needed to secure reliable averages that represent the true yielding ability. Guard rows are useful but may complicate harvesting operations and result in a loss of accuracy in plot separation.

Our efforts are aimed first at securing a reliable estimate of the magnitude of the difference in yields, and second at the error of this difference. The preferred plan is one in which the seedling plots are alternated with the standard variety, and "Student's" method of analyses is used to estimate the reliability of the yield differences obtained.

Hepialus Pharus Druce*

A moth borer attacking sugar cane in Guatemala

By Francis X. Williams

In 1934, while working with F. A. Bianchi at Finca El Salto, Escuintla, Guatemala, on insect enemies suitable for importation against the sugar cane root grub (*Anomala orientalis* Waterhouse, Scarabeidae) in Hawaii, certain other insects, injurious or beneficial, also came to notice. Among these was *Hepialus pharus,* a somber, chiefly gray-and-brown moth of variegated pattern, with very short antennae and measuring up to nearly 3 inches across outstretched wings, and the caterpillar of which—active, naked and cylindrical—was a borer in the stems of several species of plants, including sugar cane.

The work of this caterpillar was first observed in early July, in the squarish, though grooved stems of a large coarse weed of the Labiatae, or mint family, present on the edge of a sugar cane field, and in places in an adjoining pasture, growing almost in pure stands. Subsequently, other weed-plants, including a tall stout species of Compositae with large, deeply cleft leaves, and a malvaceous shrub were found attacked by this insect, while the woody stems of forest shrubs were often tunnelled by this or another species of Hepialidae. In addition, a thick-stemmed forage grass, perhaps Napier grass, was in one instance bored in a like manner. More often the borings of *Hepialus pharus* were above ground, but in weeds they occasionally extended a short distance into the roots. A weed stem several feet tall might harbor two, or even three caterpillars along its length, the entrance to each of their borings being sheltered by a soggy enclosing curtain of frass and perhaps wood particles spun together with silk. This bulging curtain sometimes completely encircled the stem at the aperture, and though not strong, probably afforded considerable protection to the caterpillar and pupa against enemies from without. A sluggish, bright red caterpillar, which was judged to be one of the Cossidae, a family also notorious as wood borers, was more rarely found. Sometimes two or more individuals were found living amicably together, in the same large-leaved Compositae weed as is attacked by Hepialus. This red borer likewise spun a protective covering over the aperture to its tunnel. It did not occur in sugar cane.

At first it appeared that two distinct species of Hepialus caterpillars affected the cane and the various weeds above enumerated. Both types of caterpillars had large roundish, dark brown heads, a reddish-brown plate on the first segment of the thorax, and smaller paler plates on the remaining segments, but the larger type of caterpillar, attaining a length of nearly 2½ inches, had a rich coffee-brown body bearing contrasting pale yellowish plates, while the smaller type was chiefly a sort of pale smoky-brown with plates also pale, but less developed. Both types transformed into pupae. Notwithstanding the differences between the two caterpillars the writer

* Thanks are due to Dr. Guy A. K. Marshall, Chief, Imperial Bureau of Entomology, London, for identifying this moth.

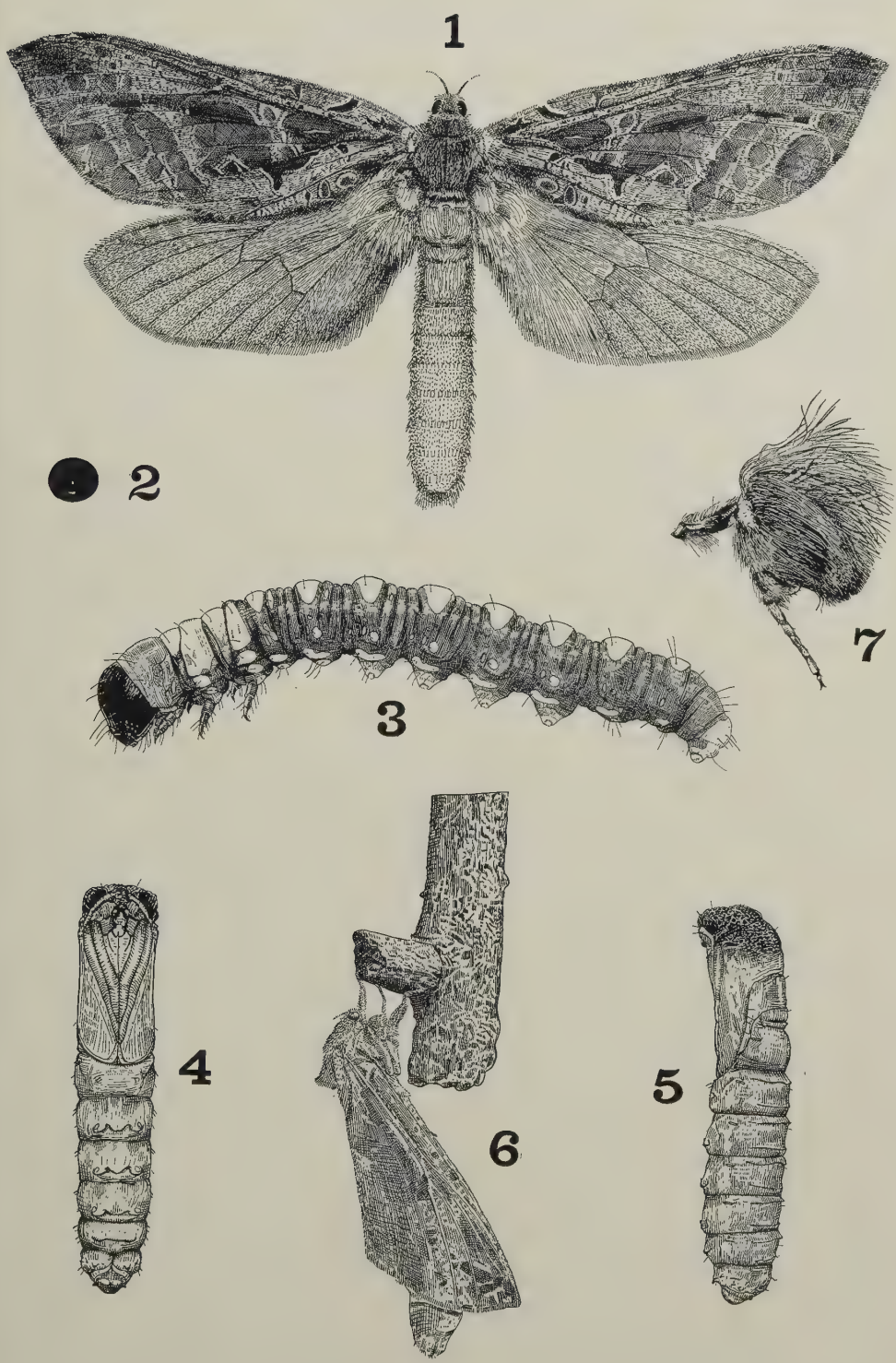


Fig. 1. *Hepialus pharus*—1. Female moth, expands to nearly 3 inches across the wings. 2. Egg; about 1/50 of an inch in diameter. 3. Full-grown caterpillar; about 2 1/3 inches long. 4. Pupa; from underside, about 1 1/8 inches long. 5. Pupa; from the side. 6. Moth at rest. 7. Hind leg of male moth.

Fig. 2. Year-old POJ cane bored and broken by the caterpillar. From an enlarged photograph.

believes that but one species, *Hepialus pharus,* was here involved. Both sorts of caterpillars were found in the weed stems and both, I believe, in sugar cane, and the moths captured in the vicinity were all *H. pharus.*

The Hepialus caterpillar is a vigorous and extremely active insect, progressing forward or backward with almost equal ease in its snug tunnel. It attacks perfectly healthy sugar cane—in the cases observed the canes were 10 to 11 months old plant POJ of several varieties and generally quite succulent. Its borings occurred chiefly in cane along the margin of the field although occasionally one was found 4 or 5 cane rows within it. The neat cylindrical, and often moist borings are commonly in the very heart of the stem and hence chiefly parallel to it until, approaching a node with its harder tissues, the course becomes one of more or less transverse curves, thus insuring almost certain breakage at that point. These borings were not observed to be very extensive; they often transversed one node, sometimes there were two caterpillars per stem, or two parallel borings in one internode, but the main length of the stem would be free from attack. These tunnels were frequently no more than a few inches to a foot above ground; in one case a boring was situated about 4 feet up the cane stem.

These borers were first noticed in newly stripped sugar cane, about the middle of July. At that time they were well grown. Some of the caterpillars pupated in August while moths were observed early in September and into October, when our chief entomological work was completed. On September 10, a search for Hepialus caterpillars in cane stems revealed only pupae. But caterpillars were still to be found in weed, and shrub stems. Perhaps the more succulent and nourishing stems of sugar cane bring the insect to maturity quicker than when in the stems of the dicotyledonous plants.

The larva seems generally to keep its tunnel clear of frass, using that material in the construction of the curtain over the opening and for plugging up any old or undesirable tunnel. Before transforming into a pupa it lines a tunnel thinly with silk and stoppers up any unnecessary extension of this chamber. This pupation tunnel may be 6 inches in length and its opening to the exterior is guarded by the usual soggy cover. Finally, the Hepialus larva casts off its skin for the last time, to become a cylindrical brown pupa, blunt at either extremity and darker there, particularly at the roughened head end. The abdomen is provided, both dorsally and ventrally, with finely toothed transverse ridges. The pupa may reach a length of 28 millimeters or more, or in excess of an inch. Even in this so-called resting stage it is capable of considerable activity and can travel up or down its cylindrical chamber by means of undulatory movements of some of the ridged abdominal segments. It is sensitive to certain changes and may back down its tunnel when exposed to light.

When the time for the emergence of the perfect insect is at hand, the pupa having worked itself to the open end of the tunnel, thrusts itself part way through the curtain of frass—if indeed the latter has not already been weathered away. Now the integument of the pupa splits apart at the head and thorax above, and the hairy moth squeezing out of this pupal fissure, suspends itself nearby to await the final development of wings and other parts. Subsequently the empty pupal skin may fall to the ground instead of remaining partly extruded from the tunnel in the cane stem.

Fig. 3. Portion of cane stem showing the caterpillar in its tunnel. From an enlarged photograph.

The moth flies early in the evening and, following the general custom of its ancient family—for the Hepialidae are a primitive group of moths—the male at least, remains on the wing for a very short time, not more than 15 minutes, as observed at El Salto. He suddenly appears at a little past 6:00 p. m. to indulge in an erratic, very swift oscillatory flight over a certain spot, as along a brush-fringed path or beside a clump of vegetation. This irregular swinging-back-and-forth, a pendulum-like flight, is for the purpose of attracting the female that is then flying about. The male is provided with curiously tufted hind legs, the glands of which, diffusing an odor, are probably a further aid in attracting his prospective mate. The female lays a large number of nearly spherical greenish-white eggs that eventually turn ebony black. They are very slightly more than 0.5 millimeter in diameter. She probably drops them here and there when in flight so that the hatching caterpillars must crawl about in search of a suitable plant in which to bore. This species like many other Hepialidae is of polyphagous habit and is thus almost sure to include among its hosts some plant that is useful to man.

The moth is kept in some control by natural enemies. Ants sometimes penetrate through the frass cover of the tunnel and attack the caterpillar. Hatched puparia of what was probably a tachinid fly were found among the remains of a Hepialus pupa in a boring in sugar cane.

Hepialid moths are of considerable interest to entomologists, largely because of their peculiar habits. The mature insect is sometimes referred to as the "hanging moth," as suggested by its position when at rest (see illustration). And because of their very rapid flight we have the name "swift moths," while the satiny-white male of *Hepialus humuli* of Europe, as it hovers over some lonely meadowland at dusk is no doubt well named the "ghost-moth."

The Fluctuations of Sugars in the Leaf Blades of the Sugar Cane Plant During the Day and the Night

By Constance E. Hartt

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I. HISTORICAL INTRODUCTION

Sugar Formation in Plants (Photosynthesis) Involves Numerous Problems

During what part of the day does a cane leaf contain the most sugar? How is that sugar made, and how transported to the stem? In the process of photosynthesis, or manufacture of food by the green coloring matter of a leaf with the energy of sunlight (the process upon which our entire industry and life are dependent) just what kind of sugar is made first? Is cane sugar, our essential food, the first product of photosynthesis? Or is it a simpler type of sugar, like glucose? Or is the first product a more complex substance, such as starch? What is the nature of the chemical change which results in the immediate formation of cane sugar? Those minute, oval, green bodies which are found in certain cells of the sugar cane leaf surrounding the veins are in some way the source of all the sugar and a major portion of the wealth produced in Hawaii, yet we do not even know whether they produce the cane sugar directly, or indirectly via some simpler substance such as glucose. We do not *know*, but as will be shown presently, more and more the plant physiologists of today are coming to the opinion that the first sugar of photosynthesis is glucose.

The investigation herein reported was undertaken in an attempt to answer some of the most fundamental questions in the physiology of the sugar cane plant—questions which may have a direct practical bearing upon the problems of irrigation, ripening, fertilizer applications, and other cultural practices. This investigation is not yet complete and we are by no means ready to give final answers to the questions raised; in fact this paper is written more for the purpose of raising questions than of answering them. Because of the interesting curves which have already been obtained it is thought advisable to put them on record with some explanatory material.

Sugars, Starch, and Polysaccharides are Carbohydrates

A few introductory remarks about the compounds dealt with in this report may not be out of place. It is generally considered that the substance produced by the green plant from water and carbon dioxide is a carbohydrate. A simple definition of a carbohydrate is a compound containing carbon, hydrogen, and oxygen, the last two elements in the same proportion as they occur in water. The molecule or smallest possible particle of water contains twice as much hydrogen as oxygen and the same holds true for a carbohydrate.

We are concerned with only a few of the many carbohydrates. The simple sugar which we call glucose has the formula, $C_6H_{12}O_6$. Cane sugar, or sucrose, the product turned out by the mills, is a more complex substance, that is, its smallest particle or molecule is larger than the smallest particle of glucose. The formula of cane sugar is, $C_{12}H_{22}O_{11}$. Because cane sugar has twelve carbon units, which is twice the number found in glucose, cane sugar is called a double sugar or disaccharide, while glucose is called a single or simple sugar or monosaccharide. Starch is much more complicated than cane sugar, being composed of a great many sugar-units. Starch is therefore called a polysaccharide (or multiple sugar). The exact structure

of starch is not known. There are several other very complex carbohydrates which as a whole are called polysaccharides; it is known that they differ from one another, but the exact nature of their difference is not clearly known.

There is another simple sugar often found in plants, called fructose, which has the same formula as glucose—$C_6H_{12}O_6$—but which differs from glucose in several ways. It will not be necessary to mention these differences.

Glucose, fructose, cane sugar, starch, and polysaccharides may all be used by the plant for food. Glucose and fructose, being simple sugars, require no digestion, but can be used just as they are. The others, being more complex, must be digested before they can be used by the plant.

The difference between simple sugars and polysaccharides has been likened to the difference between a single brick and a brick wall. Just as it is work to lift up bricks and build a wall, so it is work for a plant to build up the constituent simple sugars into the large polysaccharides.

Plants contain other carbohydrates besides the ones already mentioned. Cellulose, familiar as the fibre of sugar cane, is a very complex polysaccharide and is of such a nature that it can not be digested and used as food by green plants.

The terminology of carbohydrates is complicated by the fact that each kind may have several names. Thus glucose is also called dextrose and grape sugar. Fructose is called levulose and fruit sugar. Both glucose and fructose are called "reducing sugars," not because they make fat people thin, but because they reduce or change Fehling's or Soxhlet's solutions. A mixture of glucose and fructose is often called "invert sugar" because it results from the inversion or digestion of cane sugar. Glucose and fructose are also called "hexoses" because they contain six oxygen units.

Cane sugar, named from the sugar cane plant, is the same thing chemically as beet sugar. It is also called sucrose and saccharose.

Carbohydrates are Made Through Photosynthesis, Either Directly or Indirectly

Plants which contain the green pigment chlorophyll have the ability to manufacture their own food, using carbon dioxide and water as the raw materials. The source of the carbon dioxide is the air. The principal source of water is the soil. The process takes place chiefly in the leaves. Because sunlight is absolutely necessary for this process, it is called photosynthesis (or "putting together by light"). With the exception of a process of minor importance which occurs in a few kinds of bacteria, this is the only way in which carbon can be assimilated by plants. Human beings and all animals are absolutely dependent upon photosynthesis in plants for their supplies of food, clothing, many building materials and other things. We are dependent upon the photosynthetic activities of plants of past ages for our supplies of coal, natural gas, etc. The storage of the sun's energy in food in the process of photosynthesis is of primary importance, yet the mechanism of the chemical changes involved is unknown. Anyone interested in a more complete treatment of the many important problems connected with the subject of photosynthesis is referred to Spoehr (43) and Stiles (47). The problems of particular interest to the sugar planter have been discussed by Agee (1).

What Are the Opinions of Other Workers?

Few fields of plant physiology have aroused more interest than the order of the formation of the assimilates in the process of photosynthesis. Undoubtedly the stimulus to research of this nature lies in the great practical as well as theoretical importance of the question. Comparatively little attention, however, has been paid to the physiology of sugar production in the sugar cane plant. In the following paragraphs, attention will first be directed to the more important papers concerning plants other than sugar cane; subsequently the work with the plant of greatest interest to us will be reviewed.

Briefly, the question is this: What compound is the direct product of photosynthesis? That it is a carbohydrate is of little doubt. Is it glucose, or a mixture of glucose and fructose, or sucrose, or starch? What is the origin of sucrose in the sugar cane plant? Does it arise spontaneously in the process of photosynthesis? Is it formed by the condensation or union of glucose and fructose? Is it the result of a change within the molecule (or smallest particle) of starch before digestion? Or is it made by a combination of these processes?

A. Studies With Plants Other Than Sugar Cane:

1. *Starch:* Sachs (39, 40), writing in 1862 and 1864, considered starch to be the first visible product of assimilation or photosynthesis. De Vries (16) in 1878, thought the green pigment chlorophyll first formed starch, which was hydrolized or digested to glucose, the glucose migrated to the roots and there polymeryzed (or united with itself) to form sucrose. Although the production of starch in green leaves occurs very quickly upon exposure to light, which might be considered evidence that the first assimilate in photosynthesis is starch (45), yet the total absence of starch in the onion, leek, Narcissus, and several other plants renders this view improbable. We realize that plants do not necessarily carry on their life processes according to what we consider the simplest and easiest methods, but it would seem that the production of so complex a molecule as starch at one jump would be most unlikely.

Although we may thus lay aside the view that starch is the primary assimilate, the possibility of the production of cane sugar from starch remains still to be considered. Ahrens (2) found that when starch disappears under conditions of wilting of the leaves, the starch is converted into cane sugar. Schroeder and Herrmann (42) found that in wilting nasturtium leaves the cane sugar content increased at the expense of starch. That the conversion of starch to cane sugar occurs in plants thus seems well established, but the chemical mechanism of the change is unknown. Starch is a large molecule composed of a series of glucose anhydrides or units. Cane sugar, however, is composed of one molecule or unit of fructose combined with a molecule of glucose. Therefore at some stage in the conversion of starch to cane sugar allowance must be made for the production of fructose. Whether this occurs by molecular rearrangement of some of the glucose groups in the starch chain, or by a conversion of glucose to fructose after digestion of the starch, is unknown. Very suggestive, however, is the work of Hasselbring (25) concerning carbohydrate changes in Narcissus bulbs during storage. Untreated bulbs stored at 62.6° F.

were compared with bulbs heat-treated at the middle of the storage period by immersion for four hours in water at 109.4° F. In both sets of bulbs there was a gradual loss of starch during the entire storage period, with a greater loss in the treated bulbs. Simple sugars (glucose and fructose) increased gradually until about the middle of the storage period and then receded practically to the original quantity, and this increase in simple sugars was greater in the treated bulbs. However, we are at present most interested in the fact that during the last six weeks of storage coincident with the disappearance of simple sugars an increase in cane sugar occurred. Thus in these Narcissus bulbs the following series of changes seemed to occur: starch converted to glucose, some glucose changed to fructose followed by a union of glucose and fructose to form cane sugar.

Although the degredation of starch, at least occasionally, results in the production of cane sugar, it may be stated with reasonable certainty that not all of the cane sugar in plants is formed in that way. Cane sugar is made in some plants which contain no starch; and other plants, notably sugar cane, produce considerably more cane sugar than starch. Because certain varieties of sugar cane contain more starch than others, and because certain diseases and conditions of malnutrition may increase the congestion of starch in sugar cane as well as other plants, the factors affecting the conversion of starch to cane sugar in the sugar cane plant are of considerable importance. The effect of irrigation vs. withholding water upon the production of starch and cane sugar in the sugar cane plant is now being studied, using the plants illustrated on the cover of this issue, and a brief preliminary report has already been published (24).

The conclusion seems justified that starch is not the primary assimilate. Under certain conditions, as yet not fully understood, starch may be converted into cane sugar.

2. *Cane sugar:* The theory that cane sugar is the primary assimilate in green plants was proposed in 1893 by Brown and Morris (7) in their classical researches on the chemistry and physiology of foliage leaves. Before their time it had been taken more or less for granted with little or no experimental evidence, that glucose was the primary sugar. Their analyses of the nasturtium showed fluctuations in cane sugar during the day, whereas glucose remained nearly constant in amount. Their work has been widely quoted and their paper may be considered one of the most substantial foundations of the theory that cane sugar arises as the first product of photosynthesis. However, their methods have been severely criticised, both because they analyzed dried leaf powder (in which changes undoubtedly occurred before analysis), and because their methods of estimating glucose and fructose are of doubtful value. Their contentions, therefore, should not be accepted as conclusive.

Another important paper is that of Parkin (35), published in 1912 on the carbohydrates of snowdrop leaves. Parkin found the simple sugars fairly constant in the leaf during the day and the night, while cane sugar increased during the day and decreased at night, leading him to the conclusion that cane sugar is the first sugar of photosynthesis. But Parkin's results are also not conclusive, for he used air-dried leaf powder (in which considerable changes might have occurred), and he took

samples at only two times during the 24 hours, a procedure which might easily mask any real relationship between the sugars.

Probably the most important of the modern studies supporting the view that cane sugar is the primary product of photosynthesis is the series by Davis, Daish, and Sawyer (12, 13, 14) published in 1916. They were very careful with their methods, which until lately were not questioned with the exception of their method of distinguishing between glucose and fructose, which was questioned by the authors themselves. In their studies of the mangold leaf, Davis, Daish and Sawyer (12) obtained evidence that before and during translocation (or transportation of sugar from the leaf to the stem) there is an inversion or digestion of cane sugar to simple sugars, and concluded that cane sugar was thus the primary sugar in the leaf. But, as has been pointed out by Stiles (47) this conclusion is not justified, inasmuch as it is quite reasonable to assume that the simple sugars are formed first, are then changed to cane sugar for temporary storage, and later digested to simple sugars for translocation. As a matter of fact, at least one of their experiments indicates that the simple sugars are formed first; their curves obtained on September 10-11 when smoothed show an increase in simple sugar from 10 a. m. to 6 p. m. followed by a decrease until 8 a. m., whereas cane sugar showed no significant increase until 4 p. m., increasing from 4 p. m. to 2 a. m. and then decreasing. Thus in that particular experiment at least, a formation of simple sugar must have occurred before cane sugar was made.

In another paper, Davis and Sawyer (14) state that unless sucrose is the first sugar, it is difficult to see why it predominates in leaves of such different plants as potato, grape, sunflower, and snowdrop (evidently disregarding two of their own experiments with the mangold in which the simple sugars predominated in the leaves). As has been pointed out by Dixon and Mason (17), Priestly (36) and others, the difficulty of Davis and Sawyer is readily overcome by assuming that the predominance of sucrose is due to its being a temporary storage product and that the simple sugars are always the transitory forerunners of cane sugar.

The three series of studies just reviewed (Brown and Morris; Parkin; Davis, Daish, and Sawyer) are the most important and most often quoted papers concluding that cane sugar arises as the first product of photosynthesis. After a thorough consideration of these papers the conclusion seems inevitable that this theory is not well supported by evidence.

3. *Simple sugars:* The investigators suggesting that the simple sugars are the first sugars formed in photosynthesis include some who think that both glucose and fructose arise simultaneously and others who suggest that glucose alone is the primary sugar. This question is complicated by the theories of the interconversion of glucose and fructose, a process known to occur although the exact mechanism in plants is not fully understood. For the sake of simplicity, the "glucose and fructose" and the "glucose alone" papers will be considered together.

The question is, are the simple sugars formed before cane sugar in photosynthesis?

Overlooking some early papers with no experimental evidence or with doubtful methods, the first paper of importance is that of Dixon and Mason (17) who in

1916 reported microchemical tests with leaves. Simple sugars in considerable concentration were found in and near the chloroplasts (minute bodies containing the green pigment), whereas cane sugar was concentrated near the vacuoles (watery spaces in the cell surrounded by protoplasm). Dixon and Mason suggested that the rise of cane sugar in the light is not a cogent argument that it is the primary sugar. Because the volume available for simple sugars (i. e., the space near the chloroplasts) is small compared with the space for cane sugar (i. e., the large vacuoles), the increase in the percentage of simple sugars is small compared with the increase in cane sugar in the light.

Priestley (36) in 1924 after summarizing the literature concluded that the simple sugars are the primary sugars of photosynthesis. According to Priestley, the simple sugars should not be expected to fluctuate in the light and dark as much as cane sugar, since as intermediate forms they may pass over readily into many other compounds and are not themselves storage forms. His unusual contention that cane sugar might be a breakdown product in cell metabolism has not been generally accepted.

Weevers (51) studied the sugars in green and yellow portions of variegated leaves. Weevers concluded that the simple sugars are formed first because both simple sugars and cane sugar were always found in the green portions, whereas cane sugar and little or no simple sugars were found in the yellow portions. Leaves of geranium deprived of sugar by being held for a period in the dark and then exposed to the light, produced first simple sugars and later cane sugar.

Spoehr (43) in 1926 reviewed the subject of the order of formation of the sugars in photosynthesis and said, "Unquestionably it would be very helpful if it were known just what the first sugar is that is produced in photosynthesis. In the present state of our knowledge glucose fits the theoretical requirements most adequately. Yet the fact cannot be entirely disregarded that the demonstration of glucose actually being the first sugar formed is still wanting."

Some advance in this demonstration has since been made by Tottingham, by Barton-Wright and Pratt, by Bulgakova, and by Clements. Tottingham and coworkers (48) in 1926 took afternoon samplings of sugar beet leaves for eleven days and found that the percentage of simple sugars followed in general the variations in solar radiation which would be expected if the simple sugars are made by photosynthesis.

Barton-Wright and Pratt (4) in 1930 reported careful studies of hourly samplings of Narcissus leaves. They found that previously darkened plants when returned to the light formed simple sugars soon after the stomatal pores opened, and later formed cane sugar. Maxima in daily curves for simple sugars were followed by increases in cane sugar, indicating condensation of simple sugar to cane sugar. They consider their evidence conclusive, that the simple sugars are formed first and later condense or unite to form cane sugar.

Bulgakova, Giubbenet, and Liubimenko (8) in 1930 in a study of the sugar beet, found a close correlation between variations in the amount of simple sugars in the parenchyma of the leaf and the duration of light, indicating that the simple sugars are the first products of photosynthesis.

Clements (10) in 1930, studied the hourly variation in sugars in the leaves of the sunflower, soybean, and potato. He found that cane sugar disappeared in the leaves in the early morning (5 to 6 a. m.) and did not reappear until sometime after photosynthesis had started and only after the simple sugars had reached a certain maximum. Then as cane sugar increased the simple sugars decreased. He concluded that the function of cane sugar in the leaf is temporary storage.

Priestley (37) in 1931 in a popular review of this subject stated, "The balance of evidence at the present time would seem to be in favour of the original supposition that glucose is the first sugar to be set free in photosynthesis."

Barton-Wright and M'Bain (5) in 1932 studied the carbohydrate metabolism of potato plants and found that an increase in cane sugar in the leaf is dependent upon a decrease in simple sugars, from which they concluded that the simple sugars are formed first in the leaf and later condense or unite to form cane sugar, thus confirming their conclusions obtained with Narcissus.

Armstrong and Armstrong (3) in 1934 after a brief review of the literature on photosynthesis present the chemists' viewpoint of the relationship between glucose and other carbohydrates. They suggest that almost all other carbohydrates, including cane sugar, arise from glucose. They take as a working hypothesis the primary position of glucose and mention "the fact that the first step in plant synthesis is to produce the highly asymmetric d-glucose."

In comparing the more important references under *Cane sugar* with those under *Simple sugars,* it is interesting that the *Cane sugar* papers are dated 1893-1916, while the *Simple sugars* papers are dated 1916-1934. More and more the plant physiologists of today are coming to the conclusion that the simple sugars are the primary assimilates in photosynthesis, and that cane sugar arises from the simple sugars.

4. *The formation of cane sugar from the simple sugars:* One of the arguments most often advanced against the theory that the plant makes cane sugar from the simple sugars, is the inability of chemists to reproduce such a process in the test tube. Although many attempts have been made, cane sugar has not yet been produced artificially. A sugar which gave all the tests for cane sugar, was made by the simultaneous action of two enzymes (invertase and phosphatase of yeast) by Oparin and Kurssanow (34). This important advance awaits confirmation.

One of the great difficulties connected with the artificial production of cane sugar is the fact that cane sugar contains both glucose and fructose, and the fructose is a special form which is very unstable. Beginning with the ordinary stable form of fructose it is impossible to make cane sugar, either in the test tube or in a plant. Because the unstable form of fructose is only very fleeting in its presence in a plant it is argued that cane sugar cannot arise naturally from the simple sugars, but must be made directly in the process of photosynthesis. Now let us examine this argument; a necessary corollary is that any other naturally occurring carbohydrate in plants which contains the unstable form of fructose must have an origin similar to cane sugar. Two such carbohydrates come to mind: raffinose, a triple sugar occurring in the beet and other plants often along with cane sugar; and inulin, a polysaccharide found in the ti, dandelion, artichoke, Dahlia, and other plants. It

seems unreasonable to suppose that all three of these substances (cane sugar, raffinose, and inulin) arise as direct products of photosynthesis. Assuming that cane sugar arises in such a way leaves the origin of raffinose and inulin still to be explained.

According to Liubimenko and Rubinov (30), inulin is made from a simple sugar in the underground stem of the dandelion. They also found sucrose along with the inulin in the dandelion, and state that the role of cane sugar is not clear but that possibly it is formed parallel with inulin and serves as a reserve carbohydrate. If there is in plants a mechanism which facilitates the condensation of the unstable form of fructose in the formation of raffinose and inulin, a similar mechanism may aid in the formation of cane sugar. The necessity for a mechanism involving the formation of inulin as well as cane sugar from the unstable form of fructose has also been mentioned by Colin (11). As a matter of fact, many plant physiologists and biochemists are assuming such a mechanism to exist. According to Gortner (21) although it is still uncertain whether glucose is the primary product of photosynthesis, it is nevertheless the unit from which are derived cane sugar and many other carbohydrates. Pringsheim (38) considers that such unstable sugars as that contained in the fructose portion of cane sugar are formed preferentially as intermediate products in the natural assimilation processes. Armstrong and Armstrong (3) recognizing the, as yet, unsolved difficulty connected with the formation of cane sugar, nevertheless place glucose as the primary sugar and suggest its transformation into almost all the naturally occurring carbohydrates, including cane sugar. Steele (46) suggests that the first product of photosynthesis may be the more reactive and unstable form of fructose along with glucose. The work of Oparin and Kurssanow (34) suggests the possibility of the importance of the enzyme phosphatase as a part of the mechanism in facilitating the condensation of the unstable fructose in the formation of cane sugar.

Burkard and Neuberg (9) reported in 1934 that the monophosphates of glucose and fructose can be isolated from beet leaves, the yields being in the ratio of approximately 1:1. The abstract states that they discuss the probability of the reaction of glucose and fructose to produce sucrose in the plant, but unfortunately their complete article is not yet available in Honolulu.

Definite proof that leaves can convert simple sugars into cane sugar has recently been published by Virtanen and Nordlund (49). Using red clover and wheat and later (33) working with beans, leaves which had previously been kept in the dark for 24 hours were placed in 10 per cent solutions of glucose or fructose for a further 24-hour period of darkness. When supplied with either glucose or fructose, the amount of cane sugar produced was about 6 per cent of the dry matter of the leaves. The authors consider that this is best explained by assuming that a mutual conversion of glucose into fructose and vice versa occurs in plant tissue and that glucose and fructose unite to form cane sugar in the leaves of plants.

To sum up the work with plants other than sugar cane, what have we learned?

The most modern evidence indicates that the simple sugars are the first products of photosynthesis, and places glucose as the center of carbohydrate metabolism from which are derived almost all of the carbohydrates in plants which of course includes

THEORETICAL ORIGIN OF CARBOHYDRATES IN PLANTS

Based on Armstrong and Armstrong, "THE CARBOHYDRATES," and other sources.

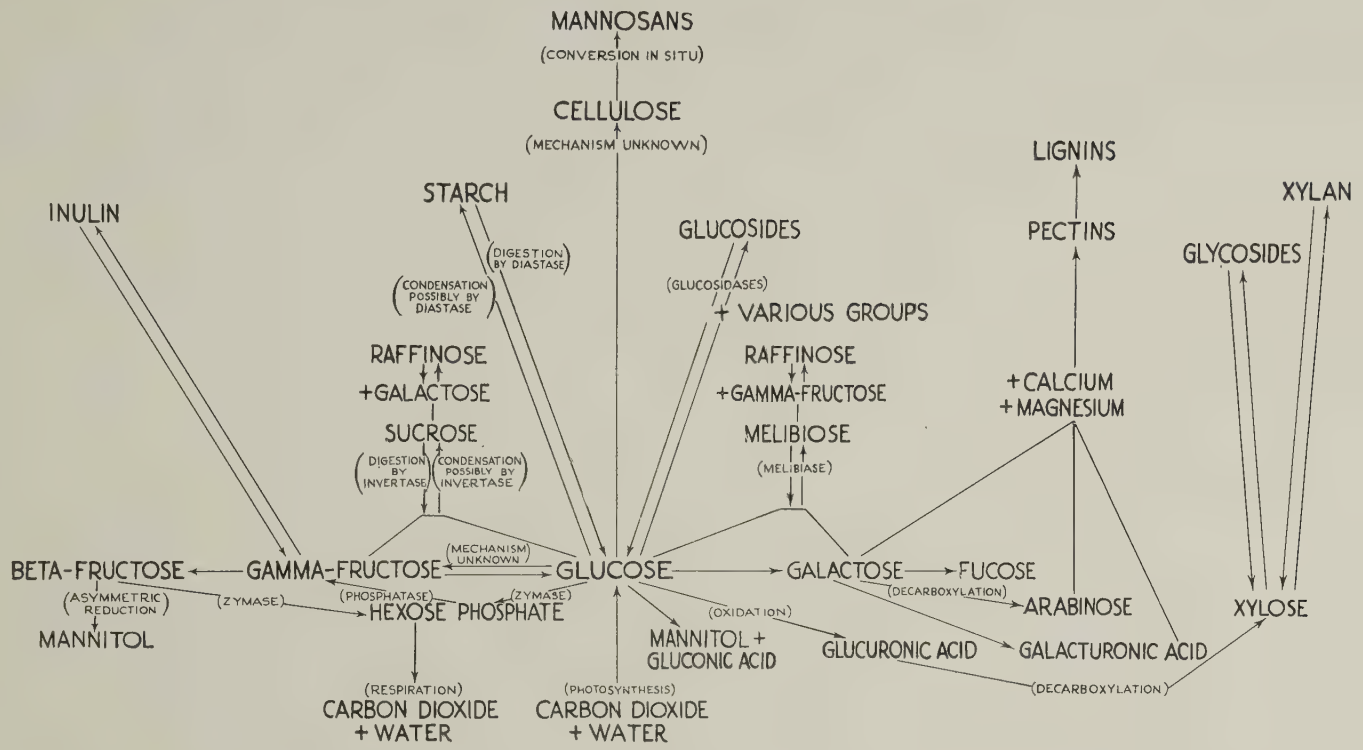


Fig. 1.

cane sugar. Starch can be converted into cane sugar. Cut leaves can make cane sugar in the dark when supplied with either glucose or fructose. Some mechanism exists in plants for the interconversion of glucose and fructose.

A diagram showing the possible relationships of the most important carbohydrate constituents in plants is presented in Fig. 1. The diagram is based on Armstrong and Armstrong (3) and other sources. Some of the changes indicated are demonstrated facts, while others are the most plausible interpretations.

B. Studies with Sugar Cane:

Inasmuch as sugar cane is one of the best sugar-producing plants in the world, it is a remarkable fact that the students investigating these important fundamental questions have seldom employed the sugar cane plant. Dr. H. A. Spoehr, the eminent authority on the subject of photosynthesis, pointed out in a lecture at the University of Hawaii (44) as well as in a private conference with the writer, that sugar cane is one of the most favorable plants for such studies and offers a unique opportunity for answering the questions raised in the introduction to this paper. Spoehr emphasized the value of conducting studies of photosynthesis in Hawaii because of the favorable climate.

One of the early studies of sugar formation in the sugar cane plant was conducted by Went (52), who was of the opinion that sucrose is the first sugar produced although as pointed out by Davis, Daish, and Sawyer (12), Went gave no evidence supporting his view. Studies both earlier and later than Went's were summarized by Viswanath (50) in 1919, who concluded that the bulk of evidence seemed to favor the view that cane sugar is built up in the stem from simple sugars sent into it by the leaf. Geerligs (20) in 1924, on the other hand, following the theory of Went, considered sucrose the first sugar. Follett-Smith (18) in 1928, sampled cane leaves at 7, 9, and 11 a. m. and 1, 3, and 5 p. m. He found that both sucrose and glucose rose during the morning and afternoon and fell in the evening, but he did not discuss the bearing of his results upon the problems of the first sugar in photosynthesis and the translocation of carbohydrates. It is unfortunate that he did not continue sampling during the night to determine the low concentrations of sugars. In another experiment (19) he collected plants at 2 p. m. for a series of days. Lower sucrose and higher glucose were found on very sunny days, while high sucrose and low glucose were found on less sunny days. This difference in sugars, however, was attributed to temperature rather than light, and explained by assuming greater inversion of sucrose on hot days.

Komatsu, Ozawa, and Makino (27) in 1933 reported a series of studies on the maturity of sugar cane. These authors are not in agreement as to what is the primary product of photosynthesis, Komatsu being of the opinion that it is a polysaccharide of the nature of starch, while Ozawa takes it for granted that a simple sugar is formed first. According to Ozawa, the most important process in the ripening of cane is the conversion of simple sugars to sucrose. Neither Komatsu nor Ozawa present experimental evidence favoring his own viewpoint. Ozawa bases an elaborate mathematical treatment of ripening upon the assumption that a simple sugar is the first product of photosynthesis.

Because of the more recent studies with other kinds of plants, most of which indicate that the simple sugars are formed first, there is need for a reconsideration of the formation of sugar in the sugar cane plant.

II. ORIGINAL RESEARCH

The writer became interested in the problems of the formation, translocation, and storage of sugar and the interrelationships between the carbohydrates in the sugar cane plant, in connection with studies of potassium deficiency in sugar cane (22, 23). Leaves of the variety H 109 when deprived of potash contained higher percentages of simple sugars, lower percentages of cane sugar, and less active invertase than the control plants which had been adequately supplied with potash. This apparent relationship between invertase and the kinds of sugars seemed best explained on the assumption that the simple sugars are formed first in photosynthesis and are later condensed to cane sugar if the invertase is sufficiently active.

Methods

In brief, the methods employed in these studies consisted in the collection of leaves at hourly or bi-hourly intervals during the day and the night, and subjecting these leaves to analysis for sugars, moisture, starch, and total polysaccharides. The leaf of the sugar cane plant consists of two distinct portions, the blade and the sheath. The blade is the flat, dark green part which is held out in the air and in which the greater part of the manufacture of food occurs. The sheath is the part which is clasped tightly around the stem; when covered entirely with other sheaths it is colorless, and when exposed to the light, it is greenish in color, but, like that of many other grasses (29), it never contains enough of the green pigment chlorophyll to carry on an important amount of photosynthesis. The most important function of the blade is the manufacture of food; the most important function of the sheath is providing a highway for the translocation of food from the blade to the stem.

In this investigation, the blades and sheaths of the same leaves were analyzed separately. The results of the studies with the blades are reported in this paper, and the data obtained from the analysis of the sheaths will be presented in a later contribution.

The Plants:

The plants were all of the variety H 109, taken from border plantings along plots at the Experiment Station. Three harvests were conducted, one in April, one in June, and one in December (1933). The plants used in April were ten months old, those in June were 12 months of age, and those in December were six months and two weeks old.

Sampling:

Counting the leaf with the highest emerged dewlap as leaf No. 1, leaves 2 and 3 (counting down) were used in all experiments. Stalks were selected the previous day and marked with white tags to facilitate sampling. Two leaves as described

above were taken each sampling hour from each of eight plants, these plants being taken at regular intervals along the entire length of the border. The blades were then rapidly separated from the sheaths, wiped, and after the removal of the midribs, were cut and then ground in a Russwin food cutter. After thorough mixing, duplicate samples for carbohydrate analyses (in December, triplicate samples) were quickly weighed and immediately plunged into boiling 95 per cent alcohol. Each sample was boiled five minutes and after the addition of another 100 cubic centimeters of boiling 95 per cent alcohol and toluene for preservation, the samples were stored in the dark until analyzed. Moisture determinations were made in the usual way. Sampling was conducted in each experiment at the hours indicated below:

April 25—p. m. 1, 3, 5, 7, 9, 11
April 26—a. m. 1, 3, 5, 6, 7, 9, 11

June 22—a. m. 4:30, 5, 5:30, 6, 6:30, 7, 7:30, 8, 9, 11
June 22—p. m. 1, 3, 5, 6, 7, 8, 9, 11
June 23—a. m. 1, 3, 4, 4:30, 5, 5:30, 6, 6:30, 7, 7:30, 8, 9

December 27—a. m. 5, 6, 7, 8, 9, 11
December 27—p. m. 1, 3, 5, 6, 7, 9, 11
December 28—a. m. 1, 3, 4, 5, 6, 7, 8, 9, 11.

Analytical Methods:

At the time of analysis the samples were extracted with hot 50 per cent alcohol, then ether, and finally 95 per cent alcohol, and were filtered. The filtrate was brought to the desired volume by the addition of 95 per cent alcohol. The sugars were then transferred from alcohol to water and concentrated on the water bath. Simple or reducing sugars (glucose and fructose) were determined by the Munson and Walker (31) method, employing the Bertrand (6) permanganate titration. Total sugars were determined by the same methods, after inversion with citric acid. Sucrose was calculated by difference. In the April experiment, the residue after extraction was used for the determination of polysaccharides, by hydrolysis with weak hydrochloric acid. In the June experiment the residue was used for the determination of starch by the Taka-diastase method of Shriner (41). Both starch and total polysaccharides were estimated in the December experiment.

Results

The April Experiment:

The results of the determinations of simple sugars, cane sugar, polysaccharides, and moisture are given in Table I, in which the first three items are expressed on the moisture-free basis. The results are graphed in Fig. 2, in which the curves have been smoothed by the method of moving averages (26). It is felt that comparisons made with graphs smoothed in this way are more reliable than the original data because this method tends to overcome the effects of individual differences and sampling errors. Solar radiation records measured by an Eppley pyreheliometer are shown in Fig. 3.

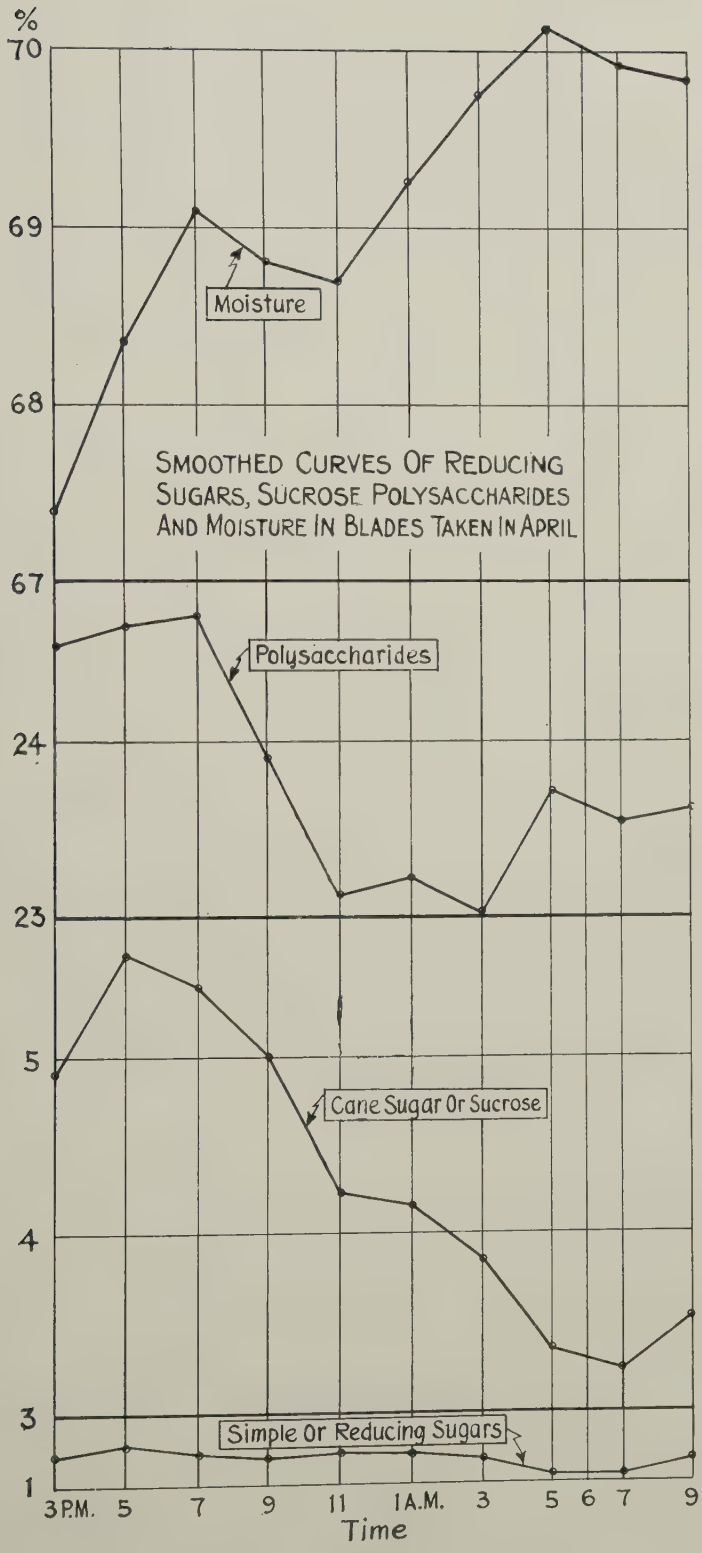
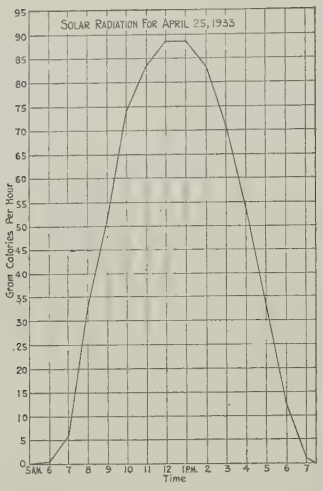
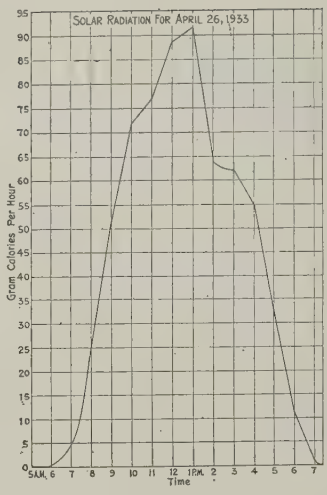
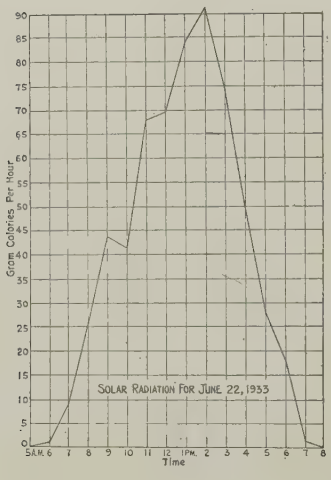
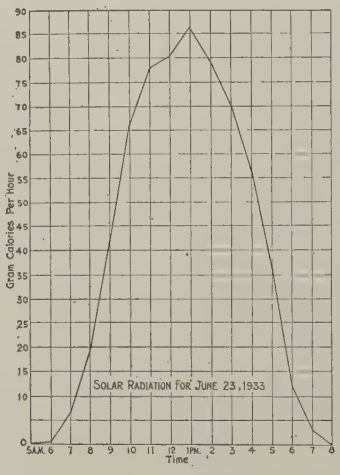

%
70
69
68
67
24
23
5
4
3
1
Moisture
SMOOTHED CURVES OF REDUCING SUGARS, SUCROSE POLYSACCHARIDES AND MOISTURE IN BLADES TAKEN IN APRIL
Polysaccharides
Cane Sugar Or Sucrose
Simple Or Reducing Sugars
3 P.M.
5
7
9
11
1 A.M.
3
5
6
7
9
Time

Fig. 2.


Solar Radiation For April 25, 1933
Gram Calories Per Hour
Time


Solar Radiation For April 26, 1933
Gram Calories Per Hour
Time


Solar Radiation For June 22, 1933
Gram Calories Per Hour
Time


Solar Radiation For June 23, 1933
Gram Calories Per Hour
Time

Solar Radiation For December 27, 1933
Gram Calories Per Hour
Time

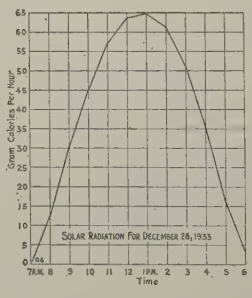

Solar Radiation For December 28, 1933
Gram Calories Per Hour
Time

Fig. 3.

TABLE I

Analyses of blades collected in April, 1933. Simple sugars, cane sugar, and polysaccharides expressed on the moisture-free basis. Also moisture percentages.

Time of Sampling	Simple Sugars	Cane Sugar	Polysaccharides	Moisture
April 25	Per Cent	Per Cent	Per Cent	Per Cent
1 p.m.	1.08±0.007	4.39±0.014	24.29±0.725	66.95±0.090
3	1.24±0.000	5.17±0.038	24.20±0.183	66.56±0.166
5	1.21±0.009	5.18±0.128	25.15±0.104	68.62±0.400
7	1.24±0.014	6.52±0.042	24.66±0.152	69.87±0.038
9	1.14±0.057	4.54±0.033	24.36±0.676	68.85±0.262
11	1.14±0.066	4.01±0.023	22.80±0.443	67.75±0.009
April 26				
1 a.m.	1.31±0.047	4.22±0.252	22.20±0.624	69.50±0.028
3	1.14±0.071	4.30±0.038	24.70±0.238	70.44±0.014
5	1.02±0.031	3.08±0.002	22.15±0.109	69.28±0.367
6	1.10±0.040	3.27±0.057	25.29±0.019	70.75±0.019
7	0.98±0.031	2.80±0.002	22.79±0.076	70.05±0.591
9	1.18±0.033	3.90±0.042	24.03±0.281	69.68±0.076
11	1.26±0.016	4.02±0.004	24.08±0.109	69.84±0.186

TABLE II

Analyses of blades collected in June. Simple sugars, cane sugar, and starch expressed on the moisture-free basis. Also moisture percentages.

Time of Sampling	Simple Sugars	Cane Sugar	Starch	Moisture
June 22	Per Cent	Per Cent	Per Cent	Per Cent
4:30 a.m.	0.864±0.009	2.295±0.033	.....	67.82±0.014
5	0.845±0.007	2.440±0.061	0.246	67.69±0.109
5:30	1.140±0.016	3.110±0.038	0.308±0.004	67.55±0.038
6	0.869±0.001	2.718	0.410±0.011	67.64±0.085
6:30	1.200±0.004	2.670	0.228	67.97
7	1.070±0.007	2.650±0.007	0.259	66.55±0.019
7:30	1.120±0.026	2.820±0.021	0.086±0.009	66.74±0.047
8	1.160±0.021	3.180±0.000	0.131±0.022	67.62±0.162
9	0.979±0.014	2.581±0.048	.....	66.27±0.057
11	1.010±0.020	3.462±0.096	0.190±0.001	66.16±0.076
1 p.m.	1.240±0.007	2.910±0.016	0.049±0.023	64.04±0.002
3	1.240±0.011	3.670±0.059	.....	64.39±0.062
5	1.090±0.009	3.940±0.031	0.255±0.010	66.38±0.281
6	1.130±0.040	3.810±0.116	0.249±0.009	67.43±0.081
7	1.010±0.002	3.680±0.059	0.270±0.005	67.03±0.085
8	1.300±0.004	3.140±0.114	0.364±0.024	67.99±0.162
9	1.200±0.009	2.470±0.045	0.304±0.021	67.53±0.019
11	0.915±0.090	2.269±0.053	0.222±0.022	68.88±0.028
June 23				
1 a.m.	0.842±0.009	1.723±0.016	0.098±0.046	69.60±0.007
3	0.924±0.028	1.925±0.068	0.000±0.000	68.82±0.033
4	0.778±0.007	2.257±0.018	0.111±0.016	66.97±0.062
4:30	0.931	2.211±0.022	0.033±0.015	68.68±0.171
5	1.004±0.007	.....	0.149±0.004	66.02±0.033
5:30	0.894±0.003	2.200±0.043	0.000±0.000	68.63±0.019
6	0.970±0.001	1.860±0.042	0.000±0.000	69.35±0.009
6:30	1.110±0.038	2.610±0.021	.....	68.16±0.042
7	1.180±0.007	2.160±0.023	0.045±0.021	69.18±0.004
7:30	1.160±0.021	1.960±0.004	0.170±0.010	67.38±0.081
8	1.030±0.000	1.830±0.038	.....	68.62±0.019
9	1.190±0.045	2.530±0.052	.....	65.35±0.019

The June Experiment:

The results of the June experiment, calculated and expressed in the same way as the April experiment, are presented in Table II and Fig. 4, and solar radiation in Fig. 3.

The December Experiment:

Sampling was conducted in triplicate in this experiment. The results of the carbohydrate analyses were calculated on the residual dry-weight basis because that is considered more accurate than the usual moisture-free basis for experiments of short duration (15). The residual dry weight equals the dry weight from which is subtracted the sum of the total sugars plus polysaccharides. The results are given in Table III and Figs. 5 and 6, and the solar radiation in Fig. 3.

TABLE III

Analyses of blades collected in December. Simple sugars, cane sugar, polysaccharides, and starch expressed on residual dry-weight basis. Also moisture percentages.

Time of Sampling	Simple Sugars	Cane Sugar	Polysaccharides	Starch	Moisture
December 27	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent
5 a.m.	1.211±0.006	2.706±0.144	30.91±0.472	0.867±0.110	72.85±0.038
6	1.482±0.015	1.572±0.391	25.85±0.767	0.936±0.010	74.22±0.028
7	1.550±0.038	2.881±0.172	31.98±0.290	0.708±0.014	74.22±0.314
8	1.624±0.028	2.567±0.084	31.16±0.620	0.757±0.052	72.90±0.000
9	1.787±0.022	2.479±0.059	31.07±0.946	1.547±0.097	73.57±0.066
11	1.672±0.030	3.150±0.175	31.76±1.327	1.613±0.056	71.03±0.262
1 p.m.	1.845±0.069	2.228±0.101	30.16±0.944	1.271±0.012	69.58±0.090
3	1.828±0.085	3.311±0.178	33.61±0.286	2.150±0.133	70.53±0.248
5	1.623±0.011	4.490±0.207	32.62±0.186	2.622±0.038	70.86±0.028
6	1.299±0.365	4.474±0.044	31.15±1.161	2.342±0.106	72.13±0.005
7	1.485±0.285	3.185±0.125	29.46±0.834	3.184±0.154	72.25±0.176
9	1.366±0.106	2.988±0.199	27.23±0.059	2.855±0.187	72.15
11	1.123±0.018	2.667±0.084	29.09±1.187	2.474±0.218	71.40±0.062
December 28					
1 a.m.	1.127±0.111	2.144±0.040	27.37±1.191	1.922±0.061	72.35
3	1.182±0.211	1.774±0.124	26.33±0.590	1.623±0.030	72.97
4	1.380±0.023	1.361±0.089	27.04±1.451	1.549±0.109	73.54
5	1.037±0.018	1.510±0.054	27.52±0.934	1.199±0.023	.....
6	1.323±0.118	1.054±0.125	23.01±0.100	0.791±0.039	73.92±0.090
7	1.159±0.039	1.450±0.131	20.22±0.057	0.774±0.042	72.85±0.085
8	0.958±0.014	1.844±0.024	21.61±0.249	0.783±0.029	71.56±0.038
9	1.269±0.166	2.473±0.111	21.49±0.255	1.117±0.036	71.01
11	1.374±0.022	3.468±0.073	24.10±0.009	1.240±0.020	70.93±0.033

Discussion

Moisture:

Definite fluctuations in moisture content occurred in all three experiments. These are shown graphically in Figs. 2, 4, and 6. It is evident that the blades of sugar cane

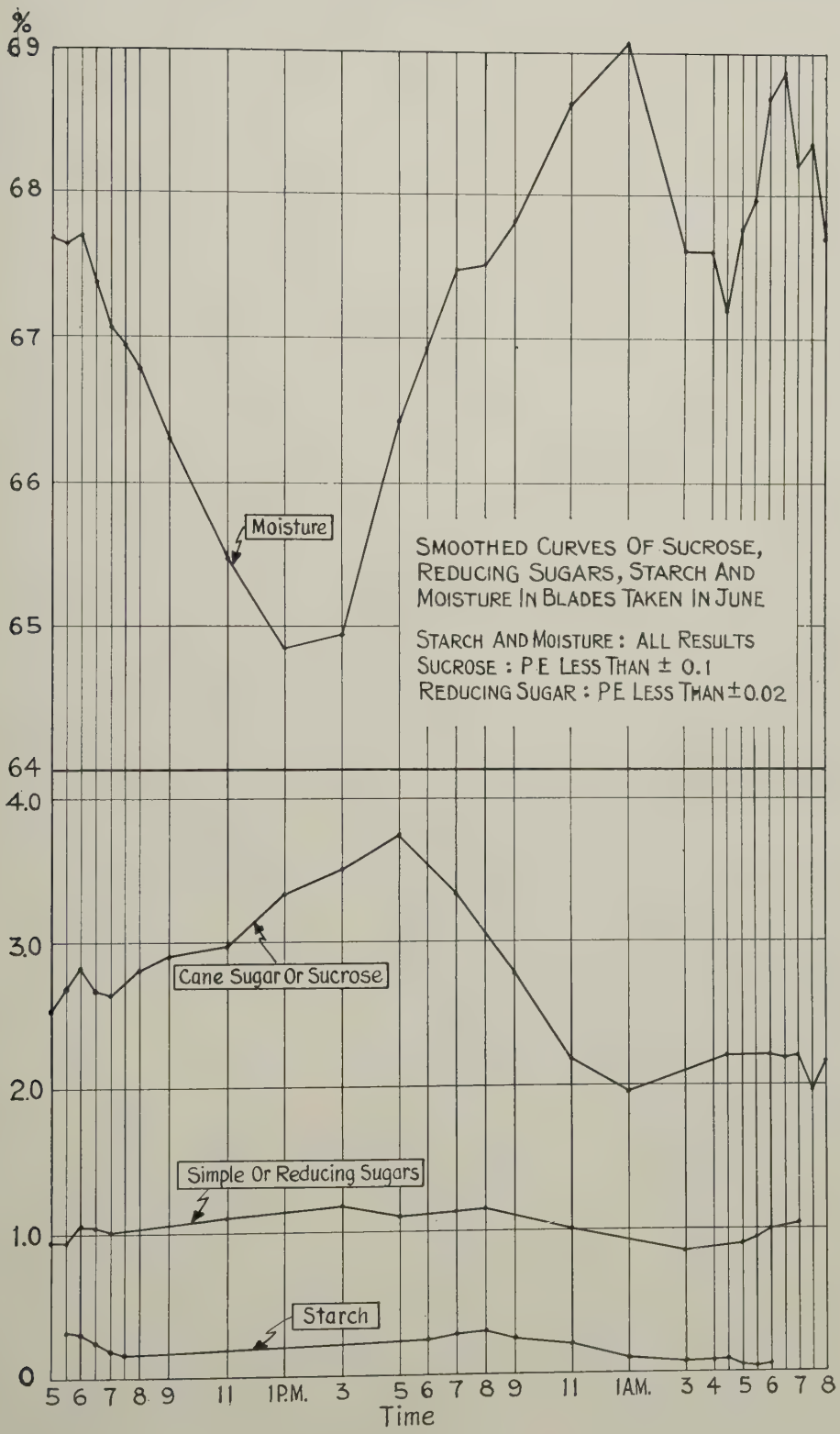

%
69
68
67
66
65
64
Moisture
SMOOTHED CURVES OF SUCROSE, REDUCING SUGARS, STARCH AND MOISTURE IN BLADES TAKEN IN JUNE
STARCH AND MOISTURE: ALL RESULTS
SUCROSE: P.E. LESS THAN ± 0.1
REDUCING SUGAR: P.E. LESS THAN ± 0.02
4.0
3.0
2.0
1.0
0
Cane Sugar Or Sucrose
Simple Or Reducing Sugars
Starch
5 6 7 8 9 11 1 P.M. 3 5 6 7 8 9 11 1 A.M. 3 4 5 6 7 8
Time

Fig. 4.

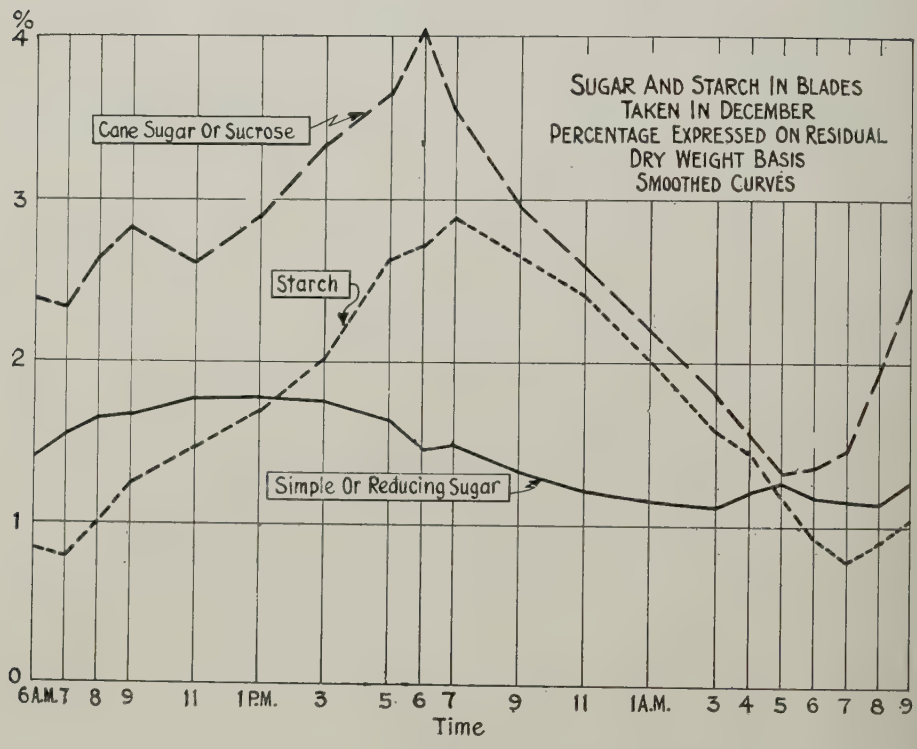

%
4
3
2
1
0
Cane Sugar Or Sucrose
Starch
Simple Or Reducing Sugar
SUGAR AND STARCH IN BLADES
TAKEN IN DECEMBER
PERCENTAGE EXPRESSED ON RESIDUAL
DRY WEIGHT BASIS
SMOOTHED CURVES
6A.M. 7 8 9 11 1P.M. 3 5 6 7 9 11 1A.M. 3 4 5 6 7 8 9
Time

Fig. 5.

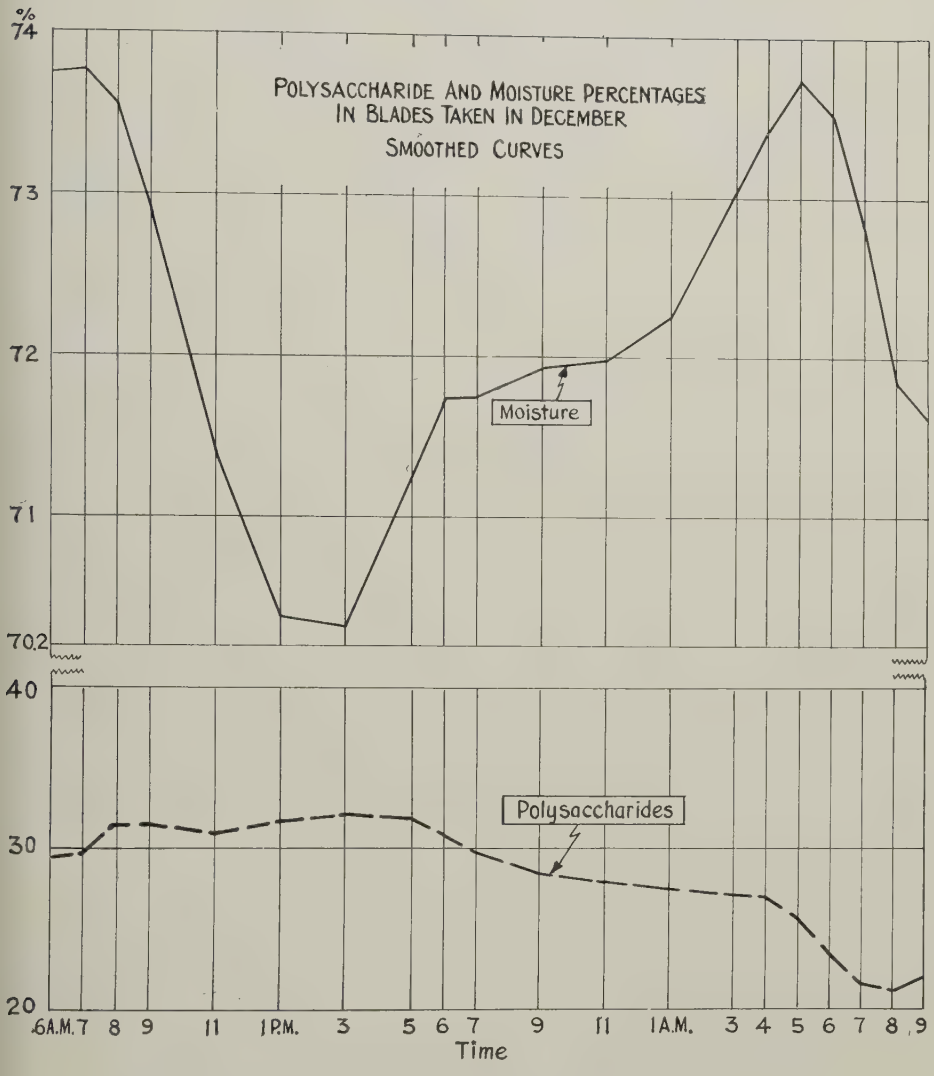

%
74
73
72
71
70.2
40
30
20
POLYSACCHARIDE AND MOISTURE PERCENTAGES
IN BLADES TAKEN IN DECEMBER
SMOOTHED CURVES
Moisture
Polysaccharides
6A.M. 7 8 9 11 1P.M. 3 5 6 7 9 11 1A.M. 3 4 5 6 7 8 9
Time

Fig. 6.

leaves contain the least water at 1 - 3 o'clock in the afternoon. This is usually the time of greatest solar radiation, with the most intense light and highest temperature. In times of drought, these are the hours of greatest danger to the leaves.

After 3 p. m., the moisture percentage increased rapidly until 6 or 7 p. m., when there was a leveling in the curve for moisture. In the April experiment an actual decrease occurred in moisture content from 7 to 11 p. m.; in June the leveling was slight and may have been due to experimental error; in December there was only a slight increase in moisture from 6 to 11 p. m., followed by a rapid rise. This cessation in the rise of the moisture percentage in the blades occurred at nightfall, thus probably at the time of stomatal closure, when one would expect an increase in moisture due to cessation of water loss through the stomatal pores. This interesting feature of the moisture content, occurring as it did in at least two of the experiments, may be a general characteristic of sugar cane leaves. Because external conditions of temperature, light and humidity, as well as stomatal closure, would lead one to expect a continuous rise in water content due to the decreasing transpiration, the decrease or leveling which actually occurred may have been due to internal causes. These moisture curves are in certain respects related to the curves for polysaccharides and as will be shown later may indicate the utilization of water in the hydrolysis of polysaccharides.

The moisture percentage of the leaves was highest in the early morning, and decreased rapidly after the coming of daylight. Therefore time of day, operating probably through light and temperature, has a profound effect upon moisture content of the blades of sugar cane.

The curves for moisture content show that the three experiments are on different levels. In the June experiment the moisture content ranged from about 65 to 69 per cent; in the April experiment from 67 to 70 per cent in round numbers, while in the December experiment the water content varied from 70 to 74 per cent. Possible explanations include variations in rainfall, in all those climatic factors generally referred to as "season," and in the age of the plant.

Rainfall during the time of the experiment does not seem to have an important effect upon the general level of water content in the blades. No rainfall at all occurred during the April and December experiments. Occasional showers occurred during the June experiment. Inasmuch as the moisture percentage was lowest in the June experiment, it would seem that some other factor is more important than rainfall in determining the water content of sugar cane leaves. Rainfall may have been responsible for the greater irregularity of the curve in the June experiment, particularly in the early morning, because it is very difficult to remove all the moisture from the surfaces of the leaves before grinding them, although every effort was made to do so.

The highest moisture percentages occurred in December, intermediate in April, and lowest in June. Although it happened that the only showers occurred in the June experiment, yet in general there is greater rainfall during December and less in June. Therefore the moisture content of the soil may have been greatest in December and that may have been the determining factor, since the importance of soil moisture in affecting the water content of plants is well known. No determinations of soil moisture were made in these experiments.

The plants used in the December experiment were six months of age, those in the April experiment 10 months old, and in the June experiment 12 months' old plants were used. Leaves from the same location on the plant were used each time in an effort to obtain comparable material, and as a result the age of the leaves differed less than the age of the plants. Whatever was the determining factor, there was an inverse relationship between the moisture content of the leaves and the age of the plant. The older the plant, the smaller the water content of the leaves.

Probably both season and age were responsible for the differences in moisture content observed in the three experiments. Which was the more important factor it is impossible to say at present.

Cane Sugar:

Striking fluctuations in sucrose content occurred during the day and the night. Cane sugar was found to increase in the blades during the day and to decrease at night. The maximum sucrose content occurred at 5 or 6 o'clock in the evening, and in each experiment this peak was followed by a rapid decrease. Thus the accumulation of cane sugar in the blades stopped with the cessation of light.

What happened in the early morning? In the April experiment sucrose decreased until 7 a. m., or until an hour after dawn. In the June experiment irregularities occurred both mornings, possibly due to rainfall; the minimum sucrose content was reached at 1 a. m.; the second morning no increase assuredly due to photosynthesis was indicated up to 8 a. m. In the December experiment sucrose reached a minimum at 7 a. m. the first day and at 5 a. m. the second day. It is interesting that sucrose did not disappear entirely from the blades at any time in any experiment. To sum up, sucrose reaches a minimum in the early morning and may begin to increase an hour before or an hour after dawn, or may show no appreciable increase even at 8 a. m. Thus some factor other than light appears to affect the time when cane sugar begins to increase in sugar cane leaves in the morning.

Among the many questions which come to mind regarding the sucrose curves, the following may be mentioned: Does the cessation of the accumulation of cane sugar at nightfall prove that sucrose is made directly in photosynthesis? Or is the fact that cane sugar does not necessarily commence to accumulate with the coming of daylight an indication that sucrose is not the primary assimilate in photosynthesis? Is the rapid decrease in cane sugar during the night caused by its inversion to glucose and fructose, or the direct translocation of cane sugar out of the blades, or by a combination of these processes? Some attempt towards a partial answer to these problems will be made after a consideration of the fluctuations of the other carbohydrate constituents in the blades.

Simple Sugars:

The simple sugars (reducing sugars) were present in much smaller amounts than cane sugar, in all three experiments. Their fluctuations during the day and the night were not as great as the fluctuations in sucrose.

Little significance could be attached to the fluctuations in simple sugars in the April experiment, considered alone, because of the relatively large experimental

error in several tests. The value of the smoothed curve for simple sugars in the April experiment is strengthened by the more evident fluctuations in June and December. Whether the greater magnitude of the fluctuations in the December experiment than in the other two experiments was due to season, to age of plant, or to more reliable results obtained from triplicate determinations, or to some other factor, we do not know. It is felt, however, that the age of the plants may have been an important factor.

In the December experiment, the maximum content of simple sugars was reached at 11 a. m., which was the time of maximum solar radiation. The simple sugars increased during the morning and decreased during the late afternoon and night. On the first morning of the December experiment, the simple or reducing sugars showed a definite increase before either starch or cane sugar had reached their minimum concentration. On the second morning in the December experiment the simple sugars increased from 3 to 5 a. m., which was before any light and therefore not due to photosynthesis. It may have been caused by the rapid hydrolysis of polysaccharides at that time. After five o'clock there was a simultaneous increase in sucrose and decrease in simple sugars, which may be evidence of condensation of simple sugars to sucrose. Sucrose began to increase at 5 a. m., starch at 7 a. m., and simple sugars at 8 a. m.

In the June experiment the relationship between the coming of light and increase in simple sugars is not clear, possibly because of rainfall. In the April experiment the simple sugars reached a minimum at 5 a. m. and began to increase after 7 a. m.

Many questions arise regarding the curves for simple sugars obtained in this investigation. Why are the simple sugars at their highest at the time of maximum solar radiation? Is their decrease during the night due to translocation, to utilization in place, or to both factors? Are their occasional increases during the night due to the hydrolysis of polysaccharides?

Starch:

Starch was not determined in the April experiment. The blades analyzed in June were very low in starch, showing a slight increase during the day and decrease at night. In the December experiment more starch was found and the fluctuations during the day and the night were considerably greater than in the June experiment.

The first day of the December experiment starch began to increase after 7 a. m. and showed a steady accumulation lasting until 7 p. m. There then followed a continuous decrease in starch until 7 a. m. the second morning and an increase from 7 to 9 a. m., the end of the experiment. The smoothed curve for starch is unencumbered by minor fluctuations, and presents a clear picture of an increase from 7 a. m. to 7 p. m., and a decrease from 7 p. m. to 7 a. m.

Only one question will be raised regarding starch. Were the higher starch content and its greater fluctuation in December than in June due to age or to season?

Polysaccharides:

Polysaccharides (or multiple sugars) include in a group such complex carbohydrates as starch, dextrine, hemicelluloses and others, and the results obtained do

not represent such a definitely known substance as starch (determined alone by the Taka-diastase method) or cane sugar or the simple sugars. Polysaccharides are considered to be reserve foods and are indirect products of photosynthesis, arising from the condensation of simple sugars. Because they are insoluble they cannot move from one place to another in a plant, but must first be digested to simple sugars before translocation can occur. This process of digestion requires water.

Polysaccharides were found to increase during the day and to decrease at night. The greatest increase occurred between 7 and 8 a. m. The most rapid decreases occurred from 5 to 7 p. m. and from 4 to 8 a. m., as shown in the December experiment. In June, polysaccharides were at a minimum during the middle of the night. The decrease in polysaccharides from 7 to 11 p. m. was accompanied by a decrease in moisture at the same time. This is only natural, inasmuch as polysaccharides can decrease only through digestion, a process which requires the utilization of water. Similarly, in the December experiment a rapid decrease in polysaccharides in the early evening was associated with a leveling in the moisture curve.

Which Sugar is Formed First in Photosynthesis?

It is impossible in the present state of our knowledge to give a decisive answer to this question. As has been explained by several authors, the greater daily fluctuations in sucrose than in the simple sugars may be used to argue either that sucrose is the first sugar or that the simple sugars are formed first, depending upon the interpretation.

It seems to the writer that the strongest evidence favoring the view that sucrose is the primary sugar is the sharp peak in the sucrose curves at nightfall, which might indicate that light is essential for the formation of cane sugar. Since it is known that light is necessary for photosynthesis, it might be argued that photosynthesis and the formation of sucrose are one and the same process, both requiring light. This does not necessarily follow. It is just as possible that light is necessary for the formation of the forerunner of sucrose, and when the supply of that forerunner is diminished, then the formation of sucrose ceases. Virtanen and Nordlund (49) found that leaves of several kinds of plants could make sucrose in the dark when supplied with either glucose or fructose. Thus it is possible that the forerunner needed for the formation of sucrose is a supply of the simple sugars, glucose and fructose, and that this supply is stopped by the lack of light. We should now ask, Is there any evidence in these experiments that the formation of sucrose depends upon the concentration of simple sugars? Is there any evidence that the concentration of simple sugars depends upon light? These two questions will now be considered.

First, Is there any evidence that the formation of cane sugar depends upon the concentration of simple sugars? Yes, there is a little such evidence in the December experiment. Sucrose decreased steadily from 6 p. m. until 5 a. m. and then increased. This increase in sucrose after 5 a. m. came immediately after an increase in simple sugars and was accompanied by a decrease in simple sugars. It may be that the decrease in sucrose was checked by the rise in simple sugars, that the increase in cane sugar which occurred before daylight was a result of the con-

densation of simple sugars, and that the formation of cane sugar was thus dependent upon the concentration of simple sugars. It may also be asked, What caused the increase in simple sugars from 3 to 5 a. m., when no photosynthesis could occur? The explanation may lie in the decrease in polysaccharides since it is known that the hydrolysis of polysaccharides leads to the formation of simple sugars.

The second question, Is there any evidence that the concentration of simple sugars depends upon light? The December experiment offers some evidence to that effect. The evidence is twofold. First, the maximum concentration of simple sugars was reached at the time of maximum solar radiation. Also, the first morning an increase in simple sugars occurred with the coming of light before sucrose began to accumulate. Neither of these points offers conclusive evidence, however, because as regards the first point, the concentration of simple sugars might have been due to temperature instead of light. The increase in simple sugars before sucrose on the first morning is also not conclusive, because it did not happen the second morning.

Now if the maximum simple sugar concentration at the time of maximum solar radiation was due to temperature rather than light, it would be due to hydrolysis, as increased temperature causes increased hydrolysis. That would mean increased hydrolysis at a time when the moisture percentage was at a minimum, which is unlikely.

There is another possible explanation for the sudden stoppage of the formation of cane sugar besides the theory that sucrose is formed directly in photosynthesis. It is possible that the action of invertase is affected by light. Evidence to this effect has recently been obtained by Murakami (32) who by the aid of filters studied the effects of single-color lights upon the action of the invertase in dried yeasts. Invertase activity was found to be stronger under red and yellow light, and weaker under green and violet light, and generally least active in the dark. The effect of light of different colors upon the activity of invertase in sugar cane has not yet been studied. If the work of Murakami can be confirmed with sugar cane and if invertase is the agent responsible for the formation of cane sugar, then it would be expected that the accumulation of sucrose would cease at nightfall. Another factor to be considered is the increasing water content, which would favor the digestion of cane sugar rather than its formation.

Thus the sharp peak in the sucrose curves at nightfall does not necessarily prove that cane sugar is the primary product of photosynthesis. The cause may lie in the cessation of the supply of a forerunner of cane sugar, in the effect of light upon the activity of invertase, the changing water content, and other factors.

If sucrose is not the first sugar in photosynthesis, then its function in the leaf is temporary storage. It must be admitted that the curve for sucrose bears a strong resemblance to the curve for starch. Starch is known to be a temporary storage product. In other words, the curve for sucrose resembles a curve for a temporary storage product. The curve for simple sugars, however, resembles a curve for a more reactive substance, with no great accumulation. Starch increased each morning at the same time sucrose increased. It may be concluded that the accumulation of sucrose and of starch are affected by the same factors. The all-important question remains, Is one of these factors the concentration of simple sugars?

Theoretically it is more plausible to consider that cane sugar is a temporary

storage product in sugar cane leaves, than to think that it is made directly in photosynthesis, for the following reason. It is well known that the piling up of end products has a retarding effect upon chemical changes, and evidence has recently been presented by Kurssanow (28) indicating that the accumulation of carbohydrates in leaves can easily lead to a lasting weakening of photosynthetic ability. Thus if cane sugar were the first product of photosynthesis its accumulation in leaves might interfere with the continuation of the photosynthetic process. If the simple sugars are formed first, their condensation to cane sugar and starch would prevent them from interfering with further photosynthesis.

Kurssanow (28) has shown that the assimilation of carbon dioxide in photosynthesis suffers a sharp depression in the middle of the day, in these plants: *Eriobotrya japonica, Pyrus Malus,* and *Cladophora* sp. This may also be true with sugar cane, inasmuch as Yap (53) found that the absorption of carbon dioxide by a cane leaf was most active from 8 to 10 a. m., decreased from 10 to 4 p. m., but was almost as active from 2 to 4 p. m. as from 8 to 10 a. m. If this were true in our December experiment, it would mean that coincident with the maximum content of simple sugars a decrease in photosynthesis occurred. This might be taken on the one hand to indicate that the maximum content of simple sugars was not caused by the maximum solar radiation if there were a decrease in photosynthesis in the middle of the day, and thus refute the suggestion made above that the concentration of simple sugars depends upon light. On the other hand it might be taken as evidence in accord with the results of Kurssanow, that the higher concentration of simple sugars has a depressing effect upon photosynthesis. The theory that the simple sugars are formed first in photosynthesis would be in agreement with the latter viewpoint and not with the former. However, all of this is highly speculative, inasmuch as no determinations of the absorption of carbon dioxide have yet been made in this research.

In conclusion, the preliminary nature of this investigation should be emphasized. The questions which arise from research of this nature are stimulating and important. The problem of the formation of sugar is being attacked from various angles, and further research will be reported as it matures. There is no doubt that the carbohydrate constituents of sugar cane blades, e.g., simple sugars, cane sugar, starch, and polysaccharides, are interrelated; that they fluctuate in concentration during the day and the night, and that a study of these fluctuations may help to elucidate some of the difficult fundamental problems of the physiology of the sugar cane plant with ultimate practical applications. Some of the questions dealing with the translocation of carbohydrates are considered in a later paper.

Acknowledgment

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The Effect of Lime Applications on Juice Quality*

By R. E. Doty

A number of lime experiments harvested along the Hilo Coast have given results showing a slight increase in cane yield from applications of lime, but such increase has been accompanied by a corresponding decrease in the quality ratio, and an actual loss in sugar.

The present test was undertaken to study, in somewhat more detail than previous tests, the effect of lime on juice quality. The site selected was a field at the Manoa substation that had an acid soil with a pH of 4.9. Lime applications at the rate of 3,700 and 10,700 pounds ($CaCO_3$) ground limestone per acre were calculated to raise this original soil pH to 6.5 and 7.8 respectively. There were twenty plots, each containing 400 square feet or .0092 acre.

The plan of fertilization follows:

1934 Crop			Fertilization—Pounds per Acre								
			July 6, 1933								
Plots	No. of Plots	Lime ($CaCO_3$ ground before planting)	A.S. 50 lbs. N	Treble Super 500 lbs. P_2O_5	Mur. Pot. 125 lbs. K_2O	Oct. 18, '33 Pot. Nit. 125 lbs. K_2O 36.9 lbs. N	Jan. 12, '34 Pot. Nit. 169.2 lbs. K_2O 50 lbs. N	Mar. 23, '34 A.S. N.S. 60 lbs. N	Totals N	Totals P_2O_5	Totals K_2O
All	20		243.9	1243.8	204.6	284.1	384.6	193.5 lbs. NS 146.3 lbs. AS	196.9	500	419
A	7	0									
B	7	3,700									
C	6	10,700									

N.S.=15.5% N
A.S.=20.5% N
Pot. Nit.=13% N, 44% K_2O
Mur. Pot.=61.1% K_2O
Treble Super=40.2% P_2O_5

* This study conducted under Project A-105, No. 29, Part I.

Procedure

The lime treatments were applied and mixed well into the soil on June 16, 1933. On July 6, 1933, the POJ 36 cane was planted and at this time the first application of fertilizer was made with the seed in shallow furrows. The remaining fertilization was carried out as indicated.

Determinations of soil pH were made for each plot before any treatment was applied and these were repeated on October 16, 1933, and again on November 2, 1934, in order to note the changes that might be occurring in the field.

The cane was harvested in three lots at ages of 16, 18 and 20 months. Samples of sound cane only were milled and juice therefrom analyzed for Brix, polarization, and glucose.

Discussion

Soil Reaction:

The original pH of the soil in these plots averaged 4.9 and the pH values desired after the application of lime, for the treatments "B" and "C," were pH 6.5 and pH 7.8 respectively. The status of the pH in the individual plots while the crop was growing is shown in Columns 4 and 5 of Table 1. The first soil samples taken four months after the applications of lime showed little deviation from the desired pH for the three series. However, more than a year later (November 2, 1934) the "A" series with its unlimed natural soil showed somewhat less acidity than originally, the "B" series had registered practically no change, while the "C" series which had been heavily limed to establish a pH of 7.8 had lost much of its alkalinity, and was but little different from the "B" series.

Weights and Analyses:

The first harvest was on November 2, 1934, when the cane was 16 months old; the second on January 3, 1935, at the age of 18 months, and the third and final harvest on March 2, when the cane was 20 months old. At each harvest the juice analysis for each plot included Brix and polarization, from which purity and quality ratio were calculated, and also glucose determinations. Comparable cane weights were secured.

Harvesting Results

The detailed data of Tables* 2, 3 and 4 are summarized in Table 2 and Figs. 1, 2, 3 and 4.

For the first harvest we note a significant loss in cane weights, a distinctly poorer purity and quality ratio, and an increased glucose content of the heavily limed "C" plots.

In the second harvest the cane weights are not significantly different but the purity and quality ratio for the heavily limed plots have been even more severely affected than in the first harvest. The effect on glucose at this harvest is not significant.

* These tables are not published here but are on file at the Experiment Station, H.S.P.A., under Project A-105, No. 29.

The third harvest shows no differences in cane yields, but the lower purity, poorer quality ratio, and increased glucose are still apparent from the plots that received the heavier applications of lime.

By this time, heavy rat damage interfered with the accuracy of the cane weights.

Observations:

The growth of the cane in the field showed marked differences at an early age. Notes made at 3 and 7 months of age showed that the high-limed ("C") plots were visibly inferior in growth to the unlimed plots.

Summary:

Supporting previous experience, the test reported here has shown definitely poorer purities and quality ratios of cane grown when lime was applied to acid soils before planting. In addition, it would appear that glucose is quite likely to be higher in the cane grown in these limed soils. The reasons for such results have not been ascertained.

TABLE 1

DETERMINATIONS OF pH BEFORE AND AFTER TREATMENT

Lime added on June 16, 1933, to bring A plots to pH 5.0;
B plots to pH 6.5 and C plots to pH 7.8.

Treatment	Plot Nos.	Original pH Dec. 29, 1932 before treatment	pH Oct. 16, 1933 4 months after treatment	pH Nov. 2, 1934
(1)	(2)	(3)	(4)	(5)
A	1	4.9	4.9	6.2
	4	4.9	4.8	5.8
	7	5.0	4.5	5.9
(no lime)	10	4.9	5.3	5.7
	13	4.9	4.6	5.8
	16	4.9	4.5	6.0
	19	4.6	4.8	5.9
Average		4.87	4.77	5.87
B	2	5.2	6.1	6.5
	5	5.2	7.3	6.7
	8	5.0	6.3	6.5
(3,700 lbs. lime)	11	5.0	6.4	6.4
	14	4.9	6.1	6.5
	17	5.0	6.3	6.5
	20	4.6	6.5	6.6
Average		4.98	6.43	6.52
C	3	5.2	7.5	6.8
	6	4.6	7.8	6.8
(10,700 lbs. lime)	9	4.9	7.2	6.6
	12	4.9	7.4	6.7
	15	4.6	7.6	6.8
	18	4.9	7.0	6.7
Average		4.85	7.4	6.73

TABLE 2*

SUMMARY OF YIELDS

Project A-105, No. 29—Part I

Plots	No. of Plots	Treatment	Gross Cane Weights	Purity	Q.R.	Glucose
		First Harvest—Age 16 Months				
A	7	pH 5.0—no lime	92.0±1.9	86.44±.23	9.31±.12	0.72±.02
B	7	pH 6.5—3,700 lbs. lime per acre	88.8±0.9	85.42±.59	9.64±.21	0.80±.06
C	6	pH 7.8—10,700 lbs. lime per acre	84.5±2.6	83.70±.52	10.26±.21	0.89±.06
		Second Harvest—Age 18 Months				
A	7	pH 5.0—no lime	72.8±2.4	88.52±.54	8.89±.16	0.57±.03
B	7	pH 6.5—3,700 lbs. lime per acre	70.9±1.5	86.66±.64	9.66±.19	0.58±.04
C	6	pH 7.8—10,700 lbs. lime per acre	70.4±2.3	84.75±.95	10.47±.23	0.52±.03
		Third Harvest—Age 20 Months				
A	7	pH 5.0—no lime	60.6±2.5	89.40±.48	8.69±.17	0.36±.02
B	7	pH 6.5—3,700 lbs. lime per acre	62.8±1.7	88.65±.43	8.96±.16	0.39±.02
C	6	pH 7.8—10,700 lbs. lime per acre	59.8±1.6	86.97±.57	9.65±.16	0.51±.04

SUMMARY OF DIFFERENCES (Student's Method)

Comparing Gain of			No. of Pairs	Purity	Signif. Odds	Q. R.**	Signif. Odds
			First Harvest—Age 16 Months				
A	(pH 5.0) over	B (pH 6.5)	6	+1.29	Low	+ .34	Low
B	(pH 6.5) over	C (pH 7.8)	6	+1.65	Low	+ .62	Low
A	(pH 5.0) over	C (pH 7.8)	6	+2.82	High	+ .96	High
			Second Harvest—Age 18 Months				
A	(pH 5.0) over	B (pH 6.5)	6	+2.50	Doubtful	+ .77	Favorable
B	(pH 6.5) over	C (pH 7.8)	6	+2.00	Low	+ .81	Doubtful
A	(pH 5.0) over	C (pH 7.8)	6	+4.54	Very high	+1.58	Very high
			Third Harvest—Age 20 Months				
A	(pH 5.0) over	B (pH 6.5)	6	+ .66	Low	+ .27	Low
B	(pH 6.5) over	C (pH 7.8)	6	+1.63	Doubtful	+ .69	Favorable to high
A	(pH 5.0) over	C (pH 7.8)	6	+2.65	Favorable	+ .96	High

* Compiled from Tables 2, 3, and 4 which may be consulted in Project File, H.S.P.A. Experiment Station Library, under A-105, No. 29.

**A + sign indicates a better quality ratio (lower figure) favoring the first treatment.

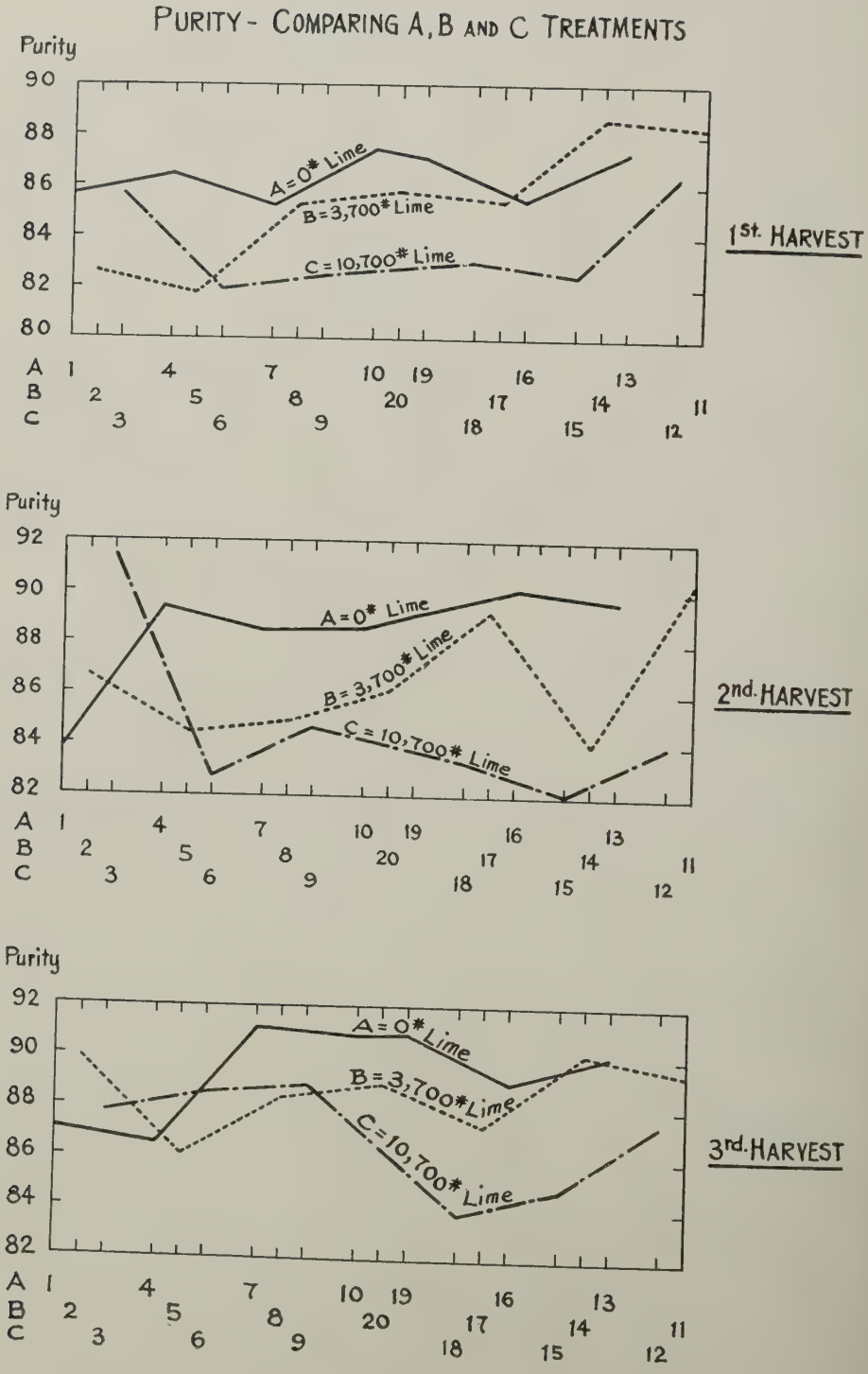

PURITY - COMPARING A, B AND C TREATMENTS
Purity
90
88
86
84
82
80
A=0* Lime
B=3,700* Lime
C=10,700* Lime
1st. HARVEST
A 1 4 7 10 19 16 13
B 2 5 8 20 17 14 11
C 3 6 9 18 15 12
Purity
92
90
88
86
84
82
A=0* Lime
B=3,700* Lime
C=10,700* Lime
2nd. HARVEST
A 1 4 7 10 19 16 13
B 2 5 8 20 17 14 11
C 3 6 9 18 15 12
Purity
92
90
88
86
84
82
A=0* Lime
B=3,700* Lime
C=10,700* Lime
3rd. HARVEST
A 1 4 7 10 19 16 13
B 2 5 8 20 17 14 11
C 3 6 9 18 15 12

Fig. 1.

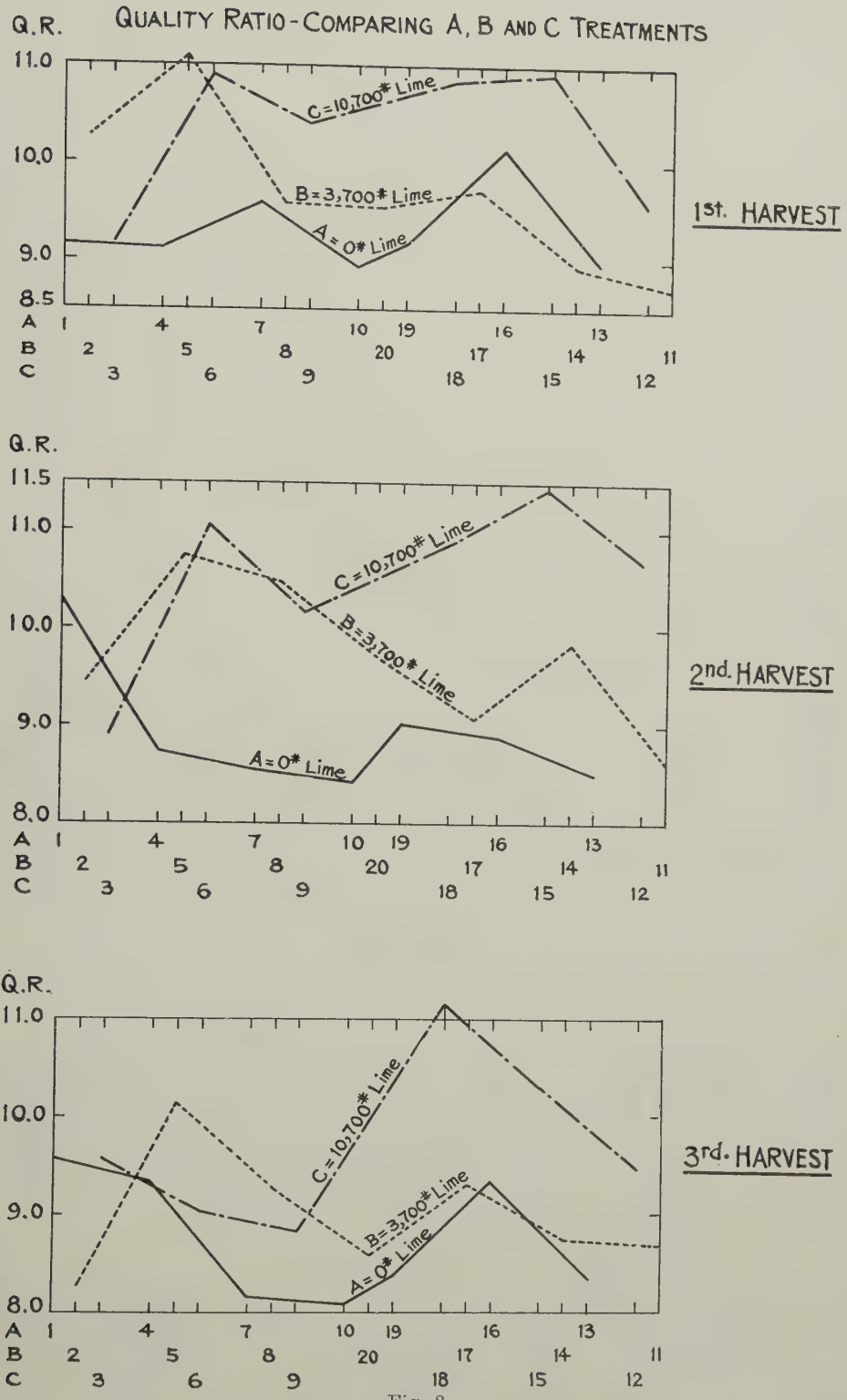
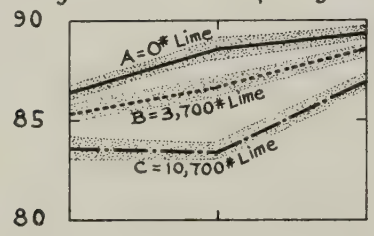

Q.R.
QUALITY RATIO - COMPARING A, B AND C TREATMENTS
11.0
10.0
9.0
8.5
C=10,700* Lime
B=3,700* Lime
A=0* Lime
1st. HARVEST
A 1 4 7 10 19 16 13
B 2 5 8 20 17 14 11
C 3 6 9 18 15 12
Q.R.
11.5
11.0
10.0
9.0
8.0
C=10,700* Lime
B=3,700* Lime
A=0* Lime
2nd. HARVEST
A 1 4 7 10 19 16 13
B 2 5 8 20 17 14 11
C 3 6 9 18 15 12
Q.R.
11.0
10.0
9.0
8.0
C=10,700* Lime
B=3,700* Lime
A=0* Lime
3rd. HARVEST
A 1 4 7 10 19 16 13
B 2 5 8 20 17 14 11
C 3 6 9 18 15 12

Fig. 2.

AVERAGE PURITY

3 Harvests

Comparing A, B and C treatments



Plots	1st. Harvest	2nd. Harvest	3rd. Harvest
A	86.44±.24	*89.29±.18 88.52±.54	89.40±.34
B	85.42±.59	86.66±.64	88.65±.28
C	83.70±.52	⊙83.38±.31 84.75±.95	86.96±.35

* = Omitting plot 1A
⊙ = Omitting plot 3C

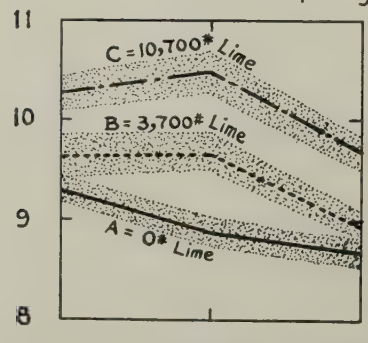
Note:- Shaded portion represents probable error zone.

Fig. 3.

AVERAGE QUALITY RATIOS

3 Harvests

Comparing A, B and C treatments



Plots	1st. Harvest	2nd. Harvest	3rd. Harvest
A	9.31±.12	8.89±.16	8.69±.17
B	9.64±.21	9.66±.19	8.96±.16
C	10.26±.21	10.47±.23	9.65±.16

Note:- Shaded portion represents probable error zone.

Fig. 4.

Ceresan Treatment of Seed Cane

By R. E. Doty

Ceresan has proven to be a great aid in securing good germination of seed cane during wet and cold weather. It is now regular practice to dip in 1 per cent Ceresan all seed which is to be planted at Kailua substation during the winter months.

The extensive work (167 tests) of R. Urata, under Dr. A. J. Mangelsdorf's direction in 1931-32 on the prevention and control of rot in sugar cane seed pieces, tested out a large number of chemicals that might offer a control. In this work there is a preponderance of evidence that Ceresan dipped seed germinates much better than untreated seed, with less seed piece rot under unfavorable conditions such as are found during the cold wet months at Kailua substation. Germinations were increased ranging from 20 to 50 per cent, with a good average around 35 per cent. H 109 showed increased germination but a slightly decreased average length of shoots. Urata (1) states: "The varieties Yellow Caledonia, POJ 2878 and POJ 36 did not show such ill effect."

The test here reported was started with H 109 seed not only to check the increase in germination due to dipping the seed in a 1 per cent solution of Ceresan but mainly to determine if there was stimulation of the young shoots after they had germinated. The test was conducted for a period of 71 days from April 9 to June 20, 1935. Unfortunately a period of bad weather in January and February prevented the plowing and preparing of the land for this test at the time scheduled. After April 1 the ground was only moderately wet and cold as compared with what it would have been from January to March. Therefore, the benefit accruing from Ceresan was greatly minimized in the present test.

Germination

The germination counts are given in the following summary:

GERMINATION COUNTS—H 109 SEED

Treatment	Number of Rows	Number of Eyes Planted	Number of Shoots Final Germination Count 71 Days After Planting	Final Per Cent Germination	Signif. by Student's Method
Ceresan	5	1104	517	49.0	
Check	5	1145	457	41.05	
			Gain for Ceresan.....	8.0	Favorable

The following chart shows the per cent germination of the primary shoots only:

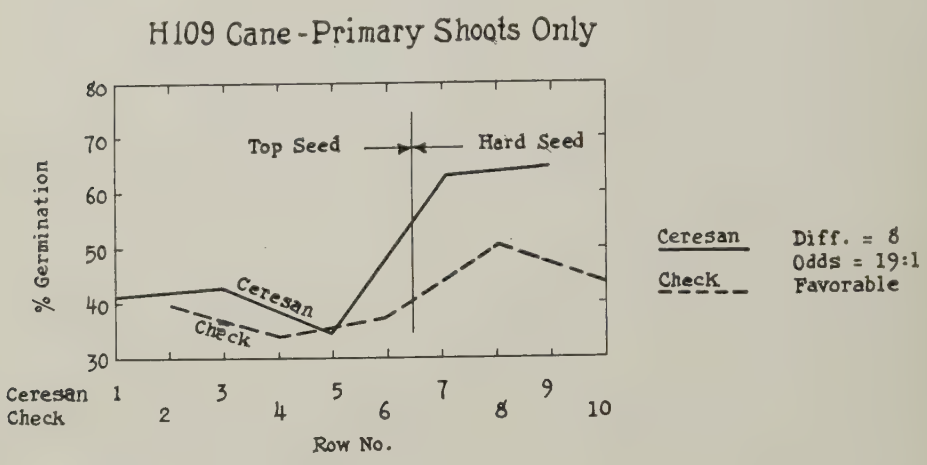


Fig. 1.

The summary of germination counts shows that the average germination percentage was increased by 8 per cent due to Ceresan treatment, with favorable significance.

A study of the graph shows that most of this benefit accrued to the hard-eyed seed, leaving very little increase to top seed. Had there been very wet weather after planting, the increased percentage favoring Ceresan would have been much larger. This has been the experience at Kailua during the winter months.

Growth of Primary Shoots

All shoots in the test were measured to the highest visible dewlap and recorded. The following table gives the results in detail:

LENGTH OF PRIMARY SHOOTS—71 DAYS AFTER PLANTING

Treatment to H 109 Seed	Number of Shoots	Total Length of Primary Shoots—Inches	Average Length of Primary Shoots—Inches	Signif. by Student's Method
Ceresan	517	3789.0	7.66	
Check	457	3791.5	8.28	
		Average loss for Ceresan....	.6	Low

The following chart was prepared from the detailed data.

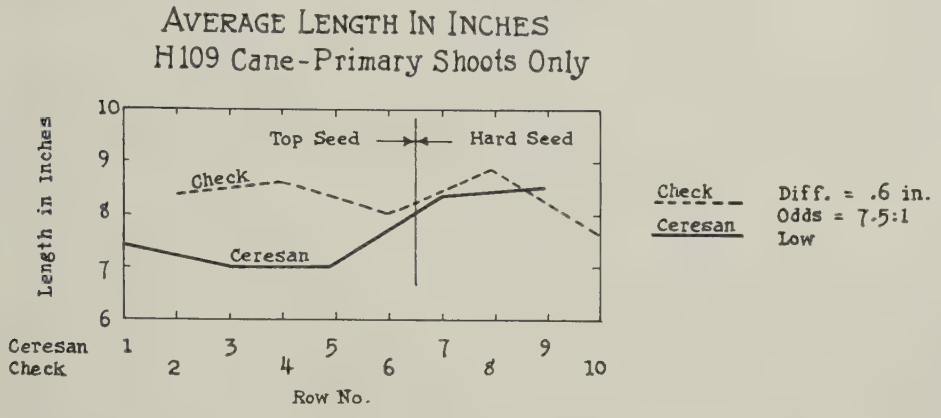


Fig. 2.

From the result it appears that the shoots of H 109 were not stimulated but rather depressed by the Ceresan treatment, there being .6 inch less growth on the Ceresan rows than in the check. Most of the depression resulting from Ceresan showed on the top seed with very little effect being evident in the hard seed. The number of row replications is too few to give significance.

This agrees with the reports of Mr. Urata on the behavior of H 109 seed mentioned earlier in this discussion.

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Sugar Prices

96° CENTRIFUGALS FOR THE PERIOD
JUNE 19, 1935, TO SEPTEMBER 6, 1935.

	Date	Per Pound	Per Ton	Remarks
June	19, 1935	3.28¢	$65.60	Cubas.
"	24	3.295	65.90	Cubas, 3.29; Puerto Ricos, 3.30.
July	15	3.29	65.80	Puerto Ricos.
"	18	3.20	64.00	Philippines.
Aug.	6	3.165	63.30	Philippines, 3.16, 3.17.
"	13	3.18	63.60	Cubas.
"	20	3.43	68.60	Philippines.
"	21	3.425	68.50	Puerto Ricos, 3.40, 3.45; Philippines, 3.45.
"	22	3.50	70.00	Cubas.
"	23	3.45	69.00	Puerto Ricos.
"	27	3.50	70.00	Puerto Ricos.
"	29	3.45	69.00	Cubas.
Sept.	6	3.50	70.00	

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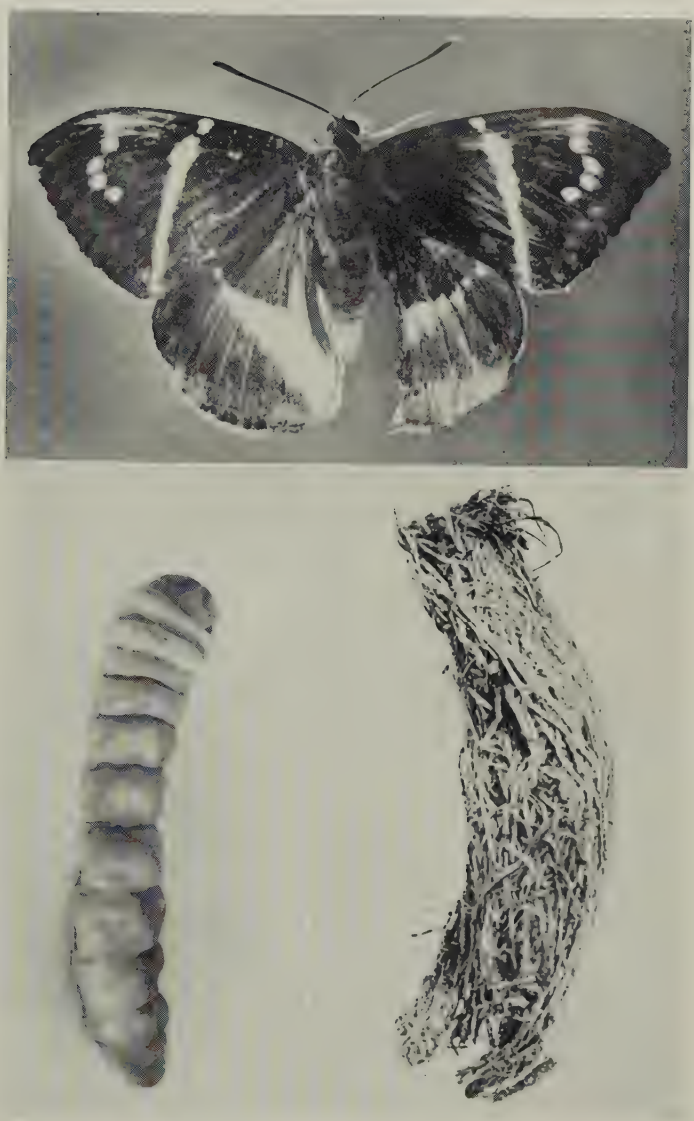
ILLUSTRATIONS APPEARING ON THE COVERS OF VOLUME XXXIX

FIRST QUARTER

Sugar cane is being crossed here under a system of mass pollination whereby several hundred cane varieties are brought together for the purpose.

SECOND QUARTER

The large sugar cane plants were grown in a complete nutrient solution which was prepared with tap water and acidified or adjusted to a pH value of 5.0 to 5.2 by adding sulphuric acid. The small plants were grown in a similar nutrient solution which was not acidified. The pH value of the latter was 5.8 to 6.0 (see text).



The giant sugar cane moth borer of Tropical America. The most serious of all insect pests of sugar cane. This moth hatched from a shipment of ornamental plants recently imported to Honolulu from the Canal Zone, Central America. Fortunately the plants were in quarantine, thus preventing the escape of the moth.

Sugar cane of the variety H 109, thirteen months of age, which is being used in a cooperative study of the effect of water upon the formation and transport of sugar and the ripening of cane.